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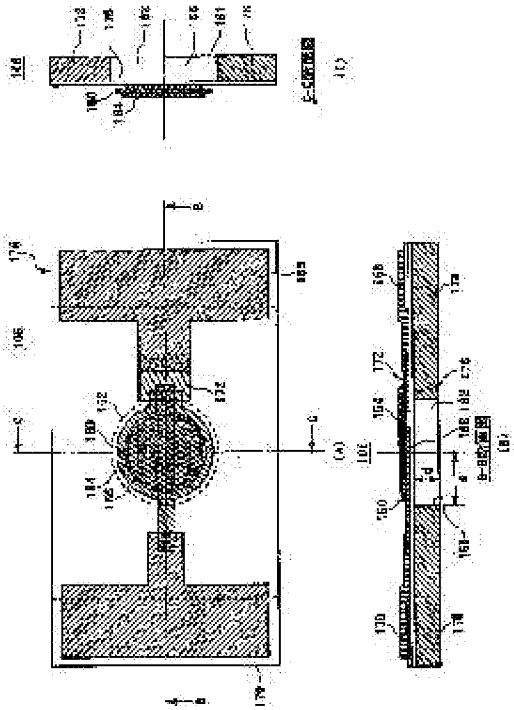
(54) **PIEZOELECTRIC DEVICE, MODULE MEMBER AND LIQUID CONTAINER**



(57)Abstract:
PROBLEM TO BE SOLVED: To accurately detect the residual amount of ink without requiring a complicated seal structure caused by the attachment of a detection electrode.
SOLUTION: In a piezoelectric device mounted on a liquid container to detect the consumption state of the liquid in the liquid container, the vibration part vibrated in the piezoelectric device has a vibration plate of which one surface comes into contact with the liquid in the liquid container, the lower electrode formed to the other surface of the vibration plate, the piezoelectric layer formed on the lower electrode and the upper electrode formed on the piezoelectric layer. In the vibration part, the piezoelectric layer is formed so as to cover the lower electrode and the upper electrode covers the lower electrode and the piezoelectric layer protrudes from the upper electrode.

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## CLAIMS

[Claim(s)]
[Claim 1] The oscillating section which is the piezoelectric device with which a liquid container is equipped, and which detects the consumption condition of the liquid in this liquid container, and vibrates in said piezoelectric device The lower electrode with which one field was formed in the field of another side of the diaphragm in contact with the liquid in a liquid container, and this diaphragm, It is the piezoelectric device which it has the piezo-electric layer formed on this lower electrode, and the up electrode formed on this piezo-electric layer, said up electrode covers a lower electrode while said oscillating section is formed so that said piezo-electric layer may cover said lower electrode, and is characterized by protruding a piezo-electric layer rather than an up electrode.
[Claim 2] Said piezoelectric device is a piezoelectric device according to claim 1 with which a top face touches the inferior-surface-of-tongue side in contact with the liquid of said diaphragm, an inferior surface of tongue is further equipped with the substrate in contact with the liquid in said liquid container, and said substrate is characterized by having the cavity which contacts a liquid in the location corresponding to the oscillating section of said diaphragm.
[Claim 3] The area of said cavity is a piezoelectric device according to claim 2 characterized by being larger than the area of said lower electrode.
[Claim 4] Deformation of said diaphragm by said residual vibration is a piezoelectric device according to claim 1 characterized by being larger than deformation of said substrate.
[Claim 5] The area of the part which generates the piezo-electric effect of said piezo-electric layer is a piezoelectric device according to claim 1 characterized by being almost the same as the area of said lower electrode.
[Claim 6] The piezoelectric device according to claim 1 with which the principal part of said up electrode, said piezo-electric layer, and said lower electrode is characterized by being a rectangle.
[Claim 7] The piezoelectric device according to claim 1 with which the principal part of said up electrode, said piezo-electric layer, and said lower electrode is characterized by the almost circular thing.
[Claim 8] The piezoelectric device according to claim 3 characterized by said cavity being almost circular and the value which broke the radius of said cavity by the depth of said cavity being larger than 3pi/8.
[Claim 9] The piezoelectric device according to claim 1 characterized by said piezoelectric device detecting the consumption condition of the liquid in said liquid container by detecting change of the acoustic impedance near [ said ] the oscillating section.
[Claim 10] The piezoelectric device according to claim 9 characterized by detecting change of said acoustic impedance based on back EMF which said piezoelectric device generates by the

residual vibration which remains in said oscillating section, and detecting the consumption condition of the liquid in said liquid container.
[Claim 11] The liquid container characterized by being equipped with a piezoelectric device according to claim 1 to 10.
[Claim 12] Said piezoelectric device is a liquid container according to claim 11 characterized by being prepared in the through-hole formed in the wall surface of a liquid container, or a crevice.
[Claim 13] It is a module object for a liquid container being equipped and detecting the consumption condition of the liquid in said liquid container. Said module object The piezoelectric device which detects the consumption condition of said liquid based on back EMF generated by residual vibration, It has the attachment structure united with said piezoelectric device for attaching said piezoelectric device in said liquid container. Said piezoelectric device The piezo-electric layer formed on the lower lower electrode this electrode with which one field was formed in the field of another side of the diaphragm in contact with the liquid in a liquid container, and this diaphragm, And it is the module object which it has the up electrode prepared on this piezo-electric layer, said up electrode covers a lower electrode while said piezo-electric layer is formed so that said lower electrode may be covered, and is characterized by having protruded the piezo-electric layer from the up electrode.
[Claim 14] Said attachment structure is a module object according to claim 13 characterized by for a top face facing the inferior-surface-of-tongue side in contact with the liquid of said diaphragm, having the attachment member to which an inferior surface of tongue contacts the liquid in said liquid container, and said attachment member having the cavity which contacts a liquid in the location of the vibrating part of said diaphragm.
[Claim 15] The module object according to claim 14 with which area of said cavity is characterized by being larger than the area of said lower electrode.
[Claim 16] The module object according to claim 13 characterized by said cavity being almost circular and the value which broke the radius of said cavity by the depth of said cavity being larger than 3pi/8.
[Claim 17] The module object according to claim 13 with which said attachment structure of said module object is characterized by said piezoelectric device being arranged in a core by said opening including opening.
[Claim 18] The area of said opening is a module object according to claim 13 characterized by being larger than the area of the part which generates the piezo-electric effect of said piezo-electric layer.
[Claim 19] Said piezoelectric device is a module object according to claim 13 characterized by the removable thing to said attachment structure.
[Claim 20] The liquid container characterized by having arranged the module object according to claim 13 to 19.

## DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Field of the Invention] This invention is detecting change of an acoustic impedance, and relates to the liquid container with which it had the piezoelectric device (actuator) for detecting the consumption condition of the liquid in the liquid container which holds liquids, such as ink, by

detecting change of resonance frequency also especially in it. In more detail, the ink of a pressure generating room is made equivalent to print data with a pressure generating means, and it pressurizes, and is related with the piezoelectric device suitable for the ink jet recording apparatus which is made to breathe out an ink droplet and is printed from a nozzle orifice, a module object, and a liquid container.

[0002]

[Description of the Prior Art] An ink jet recording device carries the ink jet recording head equipped with a pressure generating means to pressurize a pressure generating room, and the nozzle orifice which carries out the regurgitation of the pressurized ink as an ink droplet from a nozzle orifice in carriage. The ink jet recording device is constituted possible [ continuation of printing ], supplying the ink of an ink tank to a recording head through passage. When ink is consumed, the ink tank is constituted as a removable cartridge so that a user can exchange easily.

[0003] Conventionally, there is a method of managing the time of specified quantity consumption of the ink actually being carried out etc. the approach of software integrating the amount of ink attracted by the number of regurgitation of the ink droplet in a recording head, or maintenance as a management method of ink consumption of an ink cartridge, and managing ink consumption by count, and by attaching the electrode for oil-level detection in an ink cartridge.

[0004] However, the approach of software integrating the number of regurgitation and the amount of ink of an ink droplet, and managing ink consumption on count has the problem that an error arises according to the printing gestalt in a user side etc., and gross errors arise at the time of re-wearing of the same cartridge. Moreover, there was also a problem that the error which the pressure in an ink cartridge and the viscosity of ink change with the elapsed time after opening of height with a going too far room temperature or an ink cartridge etc., and cannot be disregarded between the ink consumption on count and actual consumption will arise by the operating environment. Since the method of on the other hand managing the time of ink being consumed with an electrode can detect the amount of real of ink, it can manage an ink residue with high dependability. However, since it depends for detection of the oil level of ink on the conductivity of ink, the class of detectable ink is limited and there is a problem which the seal structure of an electrode complicates. Moreover, since noble metals good [ usually ] conductivity and high were used as an ingredient of an electrode, there were corrosion resistance and a problem that the manufacturing cost of an ink cartridge increased. Furthermore, since it was necessary to equip with two electrodes, the production process increased and there was also a problem that a manufacturing cost will increase as a result.

[0005]

[Problem(s) to be Solved by the Invention] This invention relates to the liquid container with which it had the piezoelectric device for detecting the consumption condition of the liquid in the liquid container which holds a liquid by detecting change of an impedance from resonance frequency. In more detail, make the ink of a pressure generating room equivalent to print data with a pressure generating means, pressurize, and it prepares for the ink cartridge applied to the ink jet recording apparatus which is made to breathe out an ink droplet and is printed from a nozzle orifice. It is related with the piezoelectric device and module object which detect the consumption condition of the ink in an ink cartridge.

[0006]

[Means for Solving the Problem] Namely, the piezoelectric device in the 1st gestalt of this invention The oscillating section which is the piezoelectric device with which a liquid container is equipped, and which detects the consumption condition of the liquid in this liquid container,

and vibrates in a piezoelectric device The lower electrode with which one field was formed in the field of another side of the diaphragm in contact with the liquid in a liquid container, and this diaphragm, It has the up electrode formed the piezo-electric layer formed on this lower electrode, and on this piezo-electric layer, and it is desirable that the up electrode covered the lower electrode and the piezo-electric layer has overflowed rather than the up electrode while the oscillating section is formed so that a piezo-electric layer may cover a lower electrode.
[0007] Moreover, as for a piezoelectric device, it is desirable to have the cavity where a top face touches the inferior-surface-of-tongue side in contact with the liquid of a diaphragm, and an inferior surface of tongue is further equipped with the substrate in contact with the liquid in a liquid container and where a substrate contacts a liquid in the location of the vibrating part of a diaphragm. Furthermore, it is desirable that the area of a cavity is larger than the area of a lower electrode. As for deformation of the diaphragm by residual vibration, it is desirable that it is larger than deformation of a substrate. The area of the part which generates the piezo-electric effect of a piezo-electric layer may be almost the same as the area of a lower electrode. Moreover, it is desirable that the principal part of an up electrode, a piezo-electric layer, and a lower electrode is a rectangle. The principal part of an up electrode, a piezo-electric layer, and a lower electrode may be almost circular. A cavity is almost circular and it is desirable that the value which broke the radius of a cavity by the depth of a cavity is larger than 3pi/8. It is desirable that a piezoelectric device detects the consumption condition of the liquid in a liquid container by detecting change of the acoustic impedance near the oscillating section. Moreover, it is desirable that a piezoelectric device detects change of an acoustic impedance and detects the consumption condition of the liquid in a liquid container by generating back EMF by the residual vibration produced by the oscillation of a piezo-electric layer. Moreover, it is desirable that it is the liquid container with which it is equipped with the above-mentioned piezoelectric device. Furthermore, as for a piezoelectric device, it is desirable to be prepared in the through-hole formed in the wall surface of a liquid container or a crevice.
[0008] The module object in the 2nd gestalt of this invention It is a module object for a liquid container being equipped and detecting the consumption condition of the liquid in a liquid container. A module object The piezoelectric device which detects the consumption condition of a liquid by generating back EMF by the residual vibration which remains after an oscillation, It has the attachment structure united with the piezoelectric device for attaching a piezoelectric device in a liquid container. A piezoelectric device The lower electrode with which one field was formed in the field of another side of the diaphragm in contact with the liquid in a liquid container, and this diaphragm, It has the up electrode prepared on the piezo-electric layer formed on this lower electrode, and this piezo-electric layer, while a piezo-electric layer is formed so that a lower electrode may be covered, an up electrode covers a lower electrode, and as for a piezo-electric layer, having overflowed rather than the up electrode is desirable.
[0009] Furthermore, as for the attachment structure, it is desirable that a top face faces the inferior-surface-of-tongue side in contact with the liquid of a diaphragm, have the attachment member to which an inferior surface of tongue contacts the liquid in a liquid container, and an attachment member has the cavity which contacts a liquid in the location of the vibrating part of a diaphragm. Furthermore, as for the area of a cavity, it is desirable that it is larger than the area of a lower electrode. A cavity is almost circular and it is desirable that the value which broke the radius of a cavity by the depth of a cavity is larger than 3pi/8. A piezoelectric device may be arranged in a core for the attachment structure of a module object by opening including opening. Furthermore, as for the area of opening, it is desirable that it is larger than the area of the part

which generates the piezo-electric effect of a piezo-electric layer. Moreover, a piezoelectric device may be removable to the attachment structure. Furthermore, it is desirable that it is the liquid container with which the above-mentioned module object has been arranged.
[0010] In addition, the outline of the above-mentioned invention is not what enumerated all the required descriptions of this invention, and the subcombination of these characterizing group can also be invented.
[0011]
[Embodiment of the Invention] Although this invention is hereafter explained through the gestalt of implementation of invention, not all the combination of the description of the following operation gestalten that do not limit invention concerning a claim and are explained in the operation gestalt is necessarily indispensable for the solution means of invention.
[0012] The underlying concept of this invention is using an oscillating phenomenon, and is detecting the condition (the existence of the liquid in a liquid container, the amount of a liquid, the water level of a liquid, the class of liquid, and the presentation of a liquid being included) of the liquid in a liquid container. Some approaches can be considered as detection of the condition of the liquid in the liquid container using a concrete oscillating phenomenon. For example, an elastic wave generating means generates an elastic wave to the interior of a liquid container, and there is a method of detecting the medium in a liquid container and change of the condition by receiving the reflected wave reflected with an oil level or the wall which counters. Moreover, there is also the approach of detecting change of an acoustic impedance apart from this from the oscillation characteristic of the vibrating body. As an approach of using change of an acoustic impedance By vibrating the oscillating section of the piezoelectric device or actuator which has a piezoelectric device, and measuring back EMF produced by the residual vibration which remains in the oscillating section after that The approach of detecting change of an acoustic impedance by detecting resonance frequency or the back EMF wave amplitude, The impedance characteristic or admittance property of a liquid is measured with impedance analyzers, such as a measurement machine, for example, a propagation circuit etc., and there is the approach of measuring change by the frequency of the current value when giving a current value, an electrical-potential-difference value change, or vibration to a liquid or an electrical-potential-difference value. Hereafter, the detail of the principle of operation of a piezoelectric device or an actuator is explained.
[0013] Drawing 1 and drawing 2 show the detail and equal circuit of an actuator 106 which are 1 operation gestalt of a piezoelectric device. An actuator here is used for the approach of detecting change of an acoustic impedance at least and detecting the consumption condition of the liquid in a liquid container. It is used for the approach of detecting change of an acoustic impedance at least and detecting the consumption condition of the liquid in a liquid container because resonance frequency detects by residual vibration especially. Drawing 1 (A) is the expansion top view of an actuator 106. Drawing 1 (B) shows the B-B cross section of an actuator 106. Drawing 1 (C) shows the C-C cross section of an actuator 106. Furthermore, drawing 2 (A) and drawing 2 (B) show the equal circuit of an actuator 106. Moreover, drawing 2 (C) and drawing 2 (D) show the circumference containing the actuator 106 when ink is filled in the ink cartridge, respectively, and its equal circuit, and drawing 2 (E) and drawing 2 (F) show the circumference containing the actuator 106 in case there is no ink into an ink cartridge, respectively, and its equal circuit.
[0014] The substrate 178 with which an actuator 106 has the opening 161 of a circle configuration in the center mostly, The diaphragm 176 arranged in one field (henceforth a front face) of a substrate 178 so that opening 161 may be covered, The piezo-electric layer 160

arranged at the front-face side of a diaphragm 176, and the up electrode 164 and the lower electrode 166 which inserts the piezo-electric layer 160 from both, It has the auxiliary electrode 172 which is arranged between the up electrode terminal 168 electrically combined with the up electrode 164, the lower electrode terminal 170 electrically combined with the lower electrode 166, and the up electrode 164 and the up electrode terminal 168, and combines both electrically. The piezo-electric layer 160, the up electrode 164, and the lower electrode 166 have a circular part as each principal part. Each circular part of the piezo-electric layer 160, the up electrode 164, and the lower electrode 166 forms a piezoelectric device.

[0015] A diaphragm 176 is formed in the front face of a substrate 178 so that opening 161 may be covered. A cavity 162 is formed of the opening 161 of a diaphragm 176, the facing part, and the opening 161 of the front face of a substrate 178. With the piezoelectric device of a substrate 178, the field (henceforth a rear face) of the opposite side faces the liquid-container side, and the cavity 162 is constituted so that a liquid may be contacted. even if a liquid enters in a cavity 162, a liquid does not leak to the front-face side of a substrate 178 -- as -- a diaphragm 176 -- a substrate 178 -- receiving -- liquid -- it is attached densely.

[0016] The front face of a diaphragm 176, i.e., a liquid container, is located in the field of the opposite side, and the lower electrode 166 is attached so that the core of a circular part and the core of opening 161 which are the principal part of the lower electrode 166 may be mostly in agreement. In addition, it is set up so that the area of the circular part of the lower electrode 166 may become smaller than the area of opening 161. On the other hand, the piezo-electric layer 160 is formed in the front-face side of the lower electrode 166 so that the core of the circular part and the core of opening 161 may be mostly in agreement. The area of the circular part of the piezo-electric layer 160 is set up so that it may become larger than the area of the circular part of the lower electrode 166 smaller than the area of opening 161.

[0017] On the other hand, it is formed in the front-face side of the piezo-electric layer 160 so that the core of a circular part and the core of opening 161 that the up electrode 164 is the principal part may be mostly in agreement. The area of the circular part of the up electrode 164 is set up so that it may become larger than the area of the circular part of the lower electrode 166 smaller than the area of the circular parts of opening 161 and the piezo-electric layer 160.

[0018] Therefore, the principal part of the piezo-electric layer 160 has structure inserted and crowded from a front-face and rear-face side, respectively by the principal part of the up electrode 164, and the principal part of the lower electrode 166, and can carry out the deformation drive of the piezo-electric layer 160 effectively. The circular part which is each principal part of the piezo-electric layer 160, the up electrode 164, and the lower electrode 166 forms the piezoelectric device in an actuator 106. The piezoelectric device is in contact with the diaphragm 176 as mentioned above. Moreover, opening 161 has the largest area among the circular parts of the circular parts of the circular part of the up electrode 164, and the piezo-electric layer 160, and the lower electrode 166, and opening 161. The oscillating field which actually vibrates among diaphragms 176 according to this structure is determined by opening 161. Moreover, since the circular parts of the circular part of the up electrode 164 and the piezo-electric layer 160 and the circular part of the lower electrode 166 have an area smaller than opening 161, a diaphragm 176 becomes easier to vibrate. Furthermore, the circular part of the lower electrode 166 is smaller among the circular part of the lower electrode 166 electrically connected with the piezo-electric layer 160, and the circular part of the up electrode 164. Therefore, the circular part of the lower terminal 166 determines the part which generates the piezo-electric effect among the piezo-electric layers 160.

[0019] Therefore, the principal part of the piezo-electric layer 160 has structure inserted and crowded from a front-face and rear-face side, respectively by the principal part of the up electrode 164, and the principal part of the lower electrode 166, and can carry out the deformation drive of the piezo-electric layer 160 effectively. The circular part which is each principal part of the piezo-electric layer 160, the up electrode 164, and the lower electrode 166 forms the piezoelectric device in an actuator 106. The piezoelectric device is in contact with the diaphragm 176 as mentioned above. Moreover, opening 161 has the largest area among the circular parts of the circular parts of the circular part of the up electrode 164, and the piezo-electric layer 160, and the lower electrode 166, and opening 161. The oscillating field which actually vibrates among diaphragms 176 according to this structure is determined by opening 161. Moreover, since the circular parts of the circular part of the up electrode 164 and the piezo-electric layer 160 and the circular part of the lower electrode 166 have an area smaller than opening 161, a diaphragm 176 becomes easier to vibrate. Furthermore, the circular part of the lower electrode 166 is smaller among the circular part of the lower electrode 166 electrically connected with the piezo-electric layer 160, and the circular part of the up electrode 164. Therefore, the circular part of the lower terminal 166 determines the part which generates the piezo-electric effect among the piezo-electric layers 160.

[0020] The core of the circular parts of the piezo-electric layer 160 which forms a piezoelectric device, the up electrode 164, and the lower electrode 166 corresponds with the core of opening 161 mostly. moreover, the core of the opening 161 of a circle configuration of determining the vibrating part of a diaphragm 176 -- an actuator 106 -- it is mostly prepared in the core. Therefore, the core of the oscillating section of an actuator 106 is mostly in agreement with the core of an actuator. Furthermore, since the principal piece of a piezoelectric device and the vibrating part of a diaphragm 176 have a circular configuration, the oscillating section of an actuator 106 is a symmetrical configuration to the core of an actuator 106.

[0021] Since the oscillating section is a symmetrical configuration, it can be prevented from exciting an unnecessary vibration produced from the asymmetry of structure to the core of an actuator 106. Therefore, the detection precision of resonance frequency improves. Furthermore, to an actuator core, since the oscillating section is a symmetrical configuration, it is easy to manufacture it and it can make small dispersion in the configuration for every piezoelectric device. Therefore, dispersion in the resonance frequency for every piezoelectric device becomes small. Moreover, since the oscillating section is an isotropic configuration, it is hard to be influenced of dispersion in immobilization in the case of adhesion. A liquid container is pasted equally. Therefore, the mounting nature to the liquid container of an actuator 106 is good.

[0022] Furthermore, since the vibrating part of a diaphragm 176 has a circular configuration, in the resonance mode of the residual vibration of the piezo-electric layer 160, the resonance mode of a low degree, for example, primary, becomes dominant, and a single peak appears. Therefore, since a peak and a noise are clearly distinguishable, resonance frequency is clearly detectable. Moreover, by enlarging area of the vibrating part of the diaphragm 176 of a circular configuration, the difference of the back EMF wave amplitude and the amplitude of the resonance frequency by the existence of a liquid becomes large, and can improve the precision of detection of resonance frequency further.

[0023] The variation rate by vibration of a diaphragm 176 is farther [ than the variation rate by vibration of a substrate 178 ] large. Compliance is small, namely, an actuator 106 has the two-layer structure of the substrate 178 which is hard to displace by vibration, and the diaphragm 176 which compliance is large, namely, is easy to displace by vibration. According to this two-layer

structure, since the variation rate of the diaphragm 176 by vibration can be enlarged certainly being fixed to a liquid container by the substrate 178, the difference of the back EMF wave amplitude and the amplitude of the resonance frequency by the existence of a liquid becomes large, and the precision of detection of resonance frequency can be improved. Furthermore, since the compliance of a diaphragm 176 is large, attenuation of vibration becomes small and the precision of detection of resonance frequency can be improved. Moreover, the knot of vibration of an actuator 106 is located near the edge of the periphery section 161 of a cavity 162, i.e., opening.

[0024] The up electrode terminal 168 is formed in the front-face side of a diaphragm 176 so that it may connect with the up electrode 164 electrically through an auxiliary electrode 172. On the other hand, the lower electrode terminal 170 is formed in the front-face side of a diaphragm 176 so that it may connect with the lower electrode 166 electrically. Since the up electrode 164 is formed in the front-face side of the piezo-electric layer 160, it needs to have a level difference equal to the sum of the thickness of the piezo-electric layer 160, and the thickness of the lower electrode 166 while connecting with the up electrode terminal 168. The connection condition of the up electrode 164 and the up electrode terminal 168 becomes weak, and forming this level difference only with the up electrode 164 has risk of cutting, even if it is difficult and possible in a loan. Then, the up electrode 164 and the up electrode terminal 168 are connected, using an auxiliary electrode 172 as an auxiliary member. It becomes possible for the piezo-electric layer 160 and the up electrode 164 to serve as structure supported by the auxiliary electrode 172, and to be able to obtain a desired mechanical strength, and to ensure connection between the up electrode 164 and the up electrode terminal 168 by doing in this way.

[0025] In addition, the oscillating field which faces a piezoelectric device and the piezoelectric device of the diaphragms 176 is the oscillating section which actually vibrates in an actuator 106. Moreover, as for the member contained in an actuator 106, being formed in one is desirable by being calcinated mutually. By forming an actuator 106 in one, the handling of an actuator 106 becomes easy. Furthermore, an oscillation characteristic improves by raising the reinforcement of a substrate 178. That is, by raising the reinforcement of a substrate 178, only the oscillating section of an actuator 106 vibrates and any parts other than the oscillating section do not vibrate among actuators 106. Moreover, in order for any parts other than the oscillating section of an actuator 106 not to vibrate, it can attain by making the piezoelectric device of an actuator 106 thinly and small, and making a diaphragm 176 thin to raising the reinforcement of a substrate 178.

[0026] It is desirable to use the lead loess piezoelectric film which does not use PZT (PZT), the PZT lanthanum (PLZT), or lead as an ingredient of the piezo-electric layer 160, and it is desirable to use a zirconia or an alumina as an ingredient of a substrate 178. Moreover, it is desirable to use the same ingredient as a substrate 178 for a diaphragm 176. Metals, such as the ingredient which has conductivity, for example, gold, silver, copper, platinum, aluminum, and nickel, can be used for the up electrode 164, the lower electrode 166, the up electrode terminal 168, and the lower electrode terminal 170.

[0027] The actuator 106 constituted as mentioned above is applicable to the container which holds a liquid. For example, the container which held the penetrant remover for washing the ink cartridge and ink tank which are used for an ink jet recording apparatus, or a recording head can be equipped.

[0028] The predetermined location of a liquid container is equipped with the actuator 106 shown in drawing 1 and drawing 2 so that the liquid held in a liquid container in a cavity 162 may be

contacted. When the liquid is fully held in the liquid container, the inside of a cavity 162 and its outside are filled by the liquid. On the other hand, if the liquid of a liquid container is consumed and an oil level descends below to the stowed position of an actuator, a liquid does not exist in a cavity 162, or a liquid remains only in a cavity 162, and it will be in the condition that a gas exists on the outside. An actuator 106 detects the difference of an acoustic impedance as it is [ originating in change of this condition, and ] few. By it, an actuator 106 can detect whether it is in the condition that the liquid is fully held in the liquid container, or it is in the condition that a certain liquid more than fixed was consumed. Furthermore, an actuator 106 can also detect the class of liquid in a liquid container.

[0029] Here explains the principle of the oil-level detection by the actuator.

[0030] In order to detect change of the acoustic impedance of a medium, the impedance characteristic or admittance property of a medium is measured. A propagation circuit can be used when measuring an impedance characteristic or an admittance property. A propagation circuit impresses a fixed electrical potential difference to a medium, and measures the current which changes a frequency and flows to a medium. Or a propagation circuit supplies a fixed current to a medium, and measures the electrical potential difference which changes a frequency and is impressed to a medium. The current value or electrical-potential-difference value change measured by the propagation circuit shows change of an acoustic impedance. Moreover, change of the frequency fm from which a current value or an electrical-potential-difference value serves as the maximum or the minimum also shows change of an acoustic impedance.

[0031] Apart from the above-mentioned approach, an actuator can detect change of the acoustic impedance of a liquid using change of only resonance frequency. A piezoelectric device can be used, when using the approach of detecting resonance frequency by measuring back EMF produced by the residual vibration which remains in the oscillating section, as an approach of using change of the acoustic impedance of a liquid after the oscillating section of an actuator vibrates. A piezoelectric device is a component which generates back EMF by the residual vibration which remains in the oscillating section of an actuator, and the magnitude of back EMF changes with the amplitude of the oscillating section of an actuator. Therefore, it is easy to carry out detection, so that the amplitude of the oscillating section of an actuator is large. Moreover, the period from which the magnitude of back EMF changes with the frequencies of the residual vibration in the oscillating section of an actuator changes. Therefore, the frequency of the oscillating section of an actuator is equivalent to the frequency of back EMF. Here, resonance frequency says the frequency in the resonance state with the medium which touches the oscillating section and the oscillating section of an actuator.

[0032] In order to obtain resonance frequency fs, the Fourier transform of the wave acquired by the back EMF measurement in case the oscillating section and a medium are the resonance state is carried out. Since vibration of an actuator is accompanied not by deformation of only an one direction but by various deformation, such as a deflection and expanding, it has various frequencies including resonance frequency fs. Therefore, the Fourier transform of the wave of back EMF in case a piezoelectric device and a medium are the resonance state is carried out, and resonance frequency fs is judged by specifying the most dominant frequency component.

[0033] The admittance of a medium of a frequency fm is a frequency in case the maximum or an impedance is the minimum. If it is resonance frequency fs, a frequency fm will produce few errors to resonance frequency fs by dielectric loss or a mechanical loss of a medium etc. However, since time and effort is taken, generally deriving resonance frequency fs from the frequency fm surveyed replaces with and uses a frequency fm for resonance frequency. Here, an

actuator 106 can detect an acoustic impedance at least in inputting the output of an actuator 106 into a propagation circuit.
[0034] It is proved to be the approach of measuring resonance frequency fs by experiment by measuring the approach of measuring the impedance characteristic or admittance property of a medium, and measuring a frequency fm, and back EMF produced by residual vibration vibration in the oscillating section of an actuator that there is almost no difference in the resonance frequency specified as be alike.
[0035] The oscillating field of an actuator 106 is a part which constitutes the cavity 162 determined by opening 161 among diaphragms 176. When the liquid is fully held in the liquid container, in a cavity 162, a liquid is filled and an oscillating field contacts the liquid in a liquid container. On the other hand, when there is no enough liquid into a liquid container, an oscillating field does not contact a liquid in contact with the liquid which remained in the cavity in a liquid container, but contacts a gas or a vacuum.
[0036] A cavity 162 is formed in the actuator 106 of this invention, and it can design so that the liquid in a liquid container may remain in the oscillating field of an actuator 106 by it. The reason is as follows.
[0037] Although there is an oil level of the liquid in a liquid container caudad depending on [ stowed position / of an actuator ] whenever [ installation location / to the liquid container of an actuator /, or setting-angle ], a liquid may adhere to the oscillating field of an actuator. When the actuator has detected the existence of a liquid only by the existence of the liquid in an oscillating field, the liquid adhering to the oscillating field of an actuator bars exact detection of the existence of a liquid. for example, the time of the condition that there is an oil level caudad rather than the stowed position of an actuator -- both-way migration of carriage etc. -- a liquid container -- rocking -- a liquid -- a wave -- inside, if a drop adheres to an oscillating field, an actuator will make a judgment which if liquids of enough are in a liquid container mistook. Then, malfunction of an actuator can be prevented, even if it is the case where a liquid is remained conversely there and an oil level is [ a liquid container rocks and ] choppy by preparing positively the cavity designed so that the existence of a liquid might be detected correctly. Thus, malfunction can be prevented by using the actuator which has a cavity.
[0038] Moreover, as shown in drawing 2 (E), there is no liquid into a liquid container and let the case where the liquid in a liquid container remains in the cavity 162 of an actuator 106 be the threshold of the existence of a liquid. That is, there is no liquid around a cavity 162 and it judges that he has no ink when there are few liquids in a cavity than this threshold, a liquid is around a cavity 162, and when there are more liquids than this threshold, it is judged as those with ink. For example, when the side attachment wall of a liquid container is equipped with an actuator 106, the case where the liquid in a liquid container is below the stowed position of an actuator is judged to have no ink, and the case where the liquid in a liquid container is above the stowed position of an actuator is judged to be those with ink. Thus, even if it is a time of the ink in a cavity drying and ink being lost by setting up a threshold, it judges that he has no ink, and since a threshold is not exceeded even if ink adheres to a cavity again in the shake of carriage etc. at the place whose ink in a cavity was lost, it can be judged that he has no ink.
[0039] Here, the actuation and the principle which detect the condition of the liquid in a liquid container from the resonance frequency of the medium and the oscillating section of an actuator 106 by measurement of back EMF are explained, referring to drawing 1 and drawing 2 . In an actuator 106, an electrical potential difference is impressed to the up electrode 164 and the lower electrode 166 through the up electrode terminal 168 and the lower electrode terminal 170,

respectively. Electric field arise into the part pinched by the up electrode 164 and the lower electrode 166 among the piezo-electric layers 160. The piezo-electric layer 160 deforms by the electric field. When the piezo-electric layer 160 deforms, the oscillating field of the diaphragms 176 oscillates flexurally. After the piezo-electric layer 160 deforms, flexural oscillation remains in the oscillating section of an actuator 106 for the time being.

[0040] Residual vibration is the free vibration of the oscillating section of an actuator 106, and a medium. Therefore, by making into pulse shape or a square wave the electrical potential difference impressed to the piezo-electric layer 160, after impressing an electrical potential difference, the resonance state of the oscillating section and a medium can be acquired easily. Residual vibration also deforms the piezo-electric layer 160 in order to vibrate the oscillating section of an actuator 106. Therefore, the piezo-electric layer 160 generates back EMF. The back EMF is detected through the up electrode 164, the lower electrode 166, the up electrode terminal 168, and the lower electrode terminal 170. Since resonance frequency can be specified, the condition of the liquid in a liquid container is detectable with detected back EMF.

[0041] Generally, it is resonance frequency fs. fs=1/(2*pi*(M*Cact) 1/2) (formula 1)
It is come out and expressed. Here, M is the sum of the inertance Mact of the oscillating section, and addition inertance M'. Cact is the compliance of the oscillating section.

[0042] Drawing 1 (C) is the sectional view of the actuator 106 when ink does not remain in a cavity in this example. Drawing 2 (A) and drawing 2 (B) are the oscillating section of the actuator 106 when ink does not remain in a cavity, and the equal circuit of a cavity 162.

[0043] Mact should ** the product of the thickness of the oscillating section, and the consistency of the oscillating section in the area of the oscillating section, and should show it further to a detail at drawing 2 (A). Mact=Mpzt+Melectrode1+Melectrode2+Mvib (formula 2)
It is expressed. Here, Mpzt ** the product of the thickness of the piezo-electric layer 160 and the consistency of the piezo-electric layer 160 in the oscillating section in the area of the piezo-electric layer 160. Melectrode1 ** the product of the thickness of the up electrode 164 and the consistency of the up electrode 164 in the oscillating section in the area of the up electrode 164. Melectrode2 ** the product of the thickness of the lower electrode 166 and the consistency of the lower electrode 166 in the oscillating section in the area of the lower electrode 166. Mvib ** the product of the thickness of a diaphragm 176 and the consistency of a diaphragm 176 in the oscillating section in the area of the oscillating field of a diaphragm 176. However, in this example, although each area of the oscillating field of the piezo-electric layer 160, the up electrode 164, the lower electrode 166, and a diaphragm 176 has the above size relation, a minute thing is desirable [ the difference of a mutual area ], so that Mact can be computed from the thickness, the consistency, and area as the whole oscillating section. Moreover, as for parts other than the circular part which are those principal parts, in this example, it is desirable in the piezo-electric layer 160, the up electrode 164, and the lower electrode 166 that it is so minute that it can ignore to the principal part. Therefore, in an actuator 106, Mact is the sum of each inertance of the up electrode 164, the lower electrode 166, the piezo-electric layer 160, and the oscillating field of the diaphragms 176. Moreover, Compliance Cact is the compliance of the part formed of the up electrode 164, the lower electrode 166, the piezo-electric layer 160, and the oscillating field of the diaphragms 176.

[0044] In addition, although drawing 2 (A), drawing 2 (B), drawing 2 (D), and drawing 2 (F) show the oscillating section of an actuator 106, and the equal circuit of a cavity 162, in these equal circuits, Cact shows the compliance of the oscillating section of an actuator 106 . Cpzt, Celectrode1 and Celectrode2, and Cvib show the compliance of the piezo-electric layer 160 in

the oscillating section, the up electrode 164, the lower electrode 166, and a diaphragm 176, respectively. Cact is expressed with the following formulas 3.

[0045]

1-/Cact=(1-/Cpzt) +(1-/Celectrode1) +(1-/Celectrode2)+ (1-/Cvib) (formula 3)

From a formula 2 and a formula 3, drawing 2 (A) can also be expressed like drawing 2 (B).

[0046] Compliance Cact expresses the volume which can receive a medium according to the deformation when putting a pressure on the unit area of the oscillating section. Moreover, Compliance Cact may say that it expresses the ease of carrying out of deformation.

[0047] A liquid is fully held in a liquid container and drawing 2 (C) shows the sectional view of the actuator 106 in case the liquid is filled around the oscillating field of an actuator 106. A liquid is fully held in a liquid container and M'max of drawing 2 (C) expresses the maximum of an addition inertance in case the liquid is filled around the oscillating field of an actuator 106. M' max is [0048].

M'max=(pi*rho/(2*k3)) * (2*(2*k*a) 3/(3*pi))/(pi*a 2) 2 (formula 4)

(a is [ the consistency of a medium and k of the radius of the oscillating section and rho ] the wave numbers.)

[0049] It is come out and expressed. In addition, a formula 4 is materialized when the radius a of the oscillating field of an actuator 106 is circular. Addition inertance M' is an amount which shows that the mass of the oscillating section is increasing seemingly according to an operation of the medium near the oscillating section. As shown in a formula 4, M'max changes with the radius a of the oscillating section, and the consistencies rho of a medium a lot.

[0050] The wave number k is k=2* pi*fact/c. (formula 5)

(fact is the resonance frequency of the oscillating section when the liquid is not touching.) c is the rate of the sound which spreads the inside of a medium.

[0051] It is come out and expressed.

[0052] A liquid is fully held in a liquid container and drawing 2 (D) shows the oscillating section of the actuator 106 in the case of being drawing 2 (C) with which the liquid is filled around the oscillating field of an actuator 106, and the equal circuit of a cavity 162.

[0053] Although the liquid of a liquid container is consumed and drawing 2 (E) does not have a liquid around the oscillating field of an actuator 106, in the cavity 162 of an actuator 106, the sectional view of the actuator 106 when the liquid remains is shown. A formula 4 is a formula showing the greatest inertance M'max determined from the consistency rho of ink etc., when the liquid is filled by the liquid container. It is [0054] when the liquid around the oscillating field of an actuator 106 becomes a gas or a vacuum on the other hand, the liquid in a liquid container having been consumed and a liquid remaining in a cavity 162. M'= rho*t/S (formula 6)

It can express. t is the thickness of the medium in connection with vibration. S is the area of the oscillating field of an actuator 106. It is S=pi*a 2 when the radius a of this oscillating field is circular. Therefore, addition inertance M' follows a formula 4, when a liquid is fully held in a liquid container and the liquid is filled around the oscillating field of an actuator 106. On the other hand, a liquid is consumed, and a formula 6 is followed when the liquid around the oscillating field of an actuator 106 becomes a gas or a vacuum, a liquid remaining in a cavity 162.

[0055] Here, although the liquid of a liquid container is consumed and there is no liquid around the oscillating field of an actuator 106 like drawing 2 (E), addition inertance M' when the liquid remains in the cavity 162 of an actuator 106 is made into M'cav for convenience, and it distinguishes from addition inertance M'max in case the liquid is filled around the oscillating

field of an actuator 106.
[0056] Although the liquid of a liquid container is consumed and drawing 2 (F) does not have a liquid around the oscillating field of an actuator 106, in the cavity 162 of an actuator 106, the oscillating section of the actuator 106 in the case of being drawing 2 (E) in which the liquid remains, and the equal circuit of a cavity 162 are shown.
[0057] Here, the parameters related to the condition of a medium are the consistency rho of a medium, and thickness [ of a medium ] t in a formula 6. When the liquid is fully held in the liquid container, a liquid contacts the oscillating section of an actuator 106, when the liquid is not fully held in the liquid container, a liquid remains inside a cavity or a gas or a vacuum contacts the oscillating section of an actuator 106. The surrounding liquid of an actuator 106 is consumed, if the addition inertance in the process which shifts to M'cav of drawing 2 (E) from M'max of drawing 2 (C) is made into M'var, since thickness t of the consistency rho of a medium and a medium changes, addition inertance M'var will change and resonance frequency fs will also change with the hold conditions of the liquid in a liquid container. Therefore, the existence of the liquid in a liquid container is detectable by specifying resonance frequency fs. When M'cav is expressed using a formula 6, depth d of a cavity is substituted for t of a formula 6, and it is [0058]. M'cav=rho*d/S (formula 7)
It becomes.
[0059] Moreover, since a consistency rho changes with differences in a presentation even if a medium is a liquid with which classes differ mutually, addition inertance M' changes and resonance frequency fs also changes. Therefore, the class of liquid is detectable by specifying resonance frequency fs. In addition, when either ink or air contacts and it is not intermingled in the oscillating section of an actuator 106, the difference of M' can be detected even if it calculates by the formula 4.
[0060] Drawing 3 (A) is a graph which shows relation with the resonance frequency fs of the amount of the ink in an ink tank, ink, and the oscillating section. Here, ink is explained as one example of a liquid. An axis of ordinate shows resonance frequency fs, and an axis of abscissa shows the amount of ink. When an ink presentation is fixed, resonance frequency fs rises with the fall of an ink residue.
[0061] When ink is fully held in an ink container and ink is filled around the oscillating field of an actuator 106, the maximum addition inertance M'max serves as a value expressed to a formula 4. On the other hand, ink is consumed, and when ink is not filled around the oscillating field of an actuator 106, a liquid remaining in a cavity 162, addition inertance M'var is computed by the formula 6 based on thickness t of a medium. t in a formula 6 can also detect the process in which ink is gradually consumed by being small in d (referring to drawing 1 (B)) of the cavity 162 of an actuator 106, namely, making a substrate 178 thin enough since it is the thickness of the medium in connection with vibration (refer to drawing 2 (C)). Here, tink considers as the thickness of the ink in connection with vibration, and sets tink-max to tink in M'max. For example, an actuator 106 is arranged almost horizontally to the oil level of ink on the base of an ink cartridge. If ink is consumed and the oil level of ink reaches below the height of t from an actuator 106, M'var will change with formulas 6 gradually and resonance frequency fs will change with formulas 1 gradually. Therefore, as long as the oil level of ink is within the limits of t, as for an actuator 106, the consumption condition of ink is detectable gradually.
[0062] Moreover, according to the location of the oil level by consumption of ink, S in a formula 6 changes by making the oscillating field of an actuator 106 greatly or long, and arranging perpendicularly. Therefore, an actuator 106 can also detect the process in which ink is consumed

gradually. For example, an actuator 106 is arranged almost perpendicularly to the oil level of ink on the side attachment wall of an ink cartridge. If ink is consumed and the oil level of ink arrives at the oscillating field of an actuator 106, since addition inertance M' will decrease with the fall of water level, resonance frequency fs increases gradually by the formula 1. Therefore, as for an actuator 106, the oil level of ink can detect the consumption condition of ink gradually, as long as it is within the limits of path 2a (refer to drawing 2 (C)) of a cavity 162.

[0063] The curve X of drawing 3 (A) expresses relation with the resonance frequency fs of the amount of the ink held in the ink tank the case where the cavity 162 of an actuator 106 is made shallow enough, and at the time of making the oscillating field of an actuator 106 greatly enough or long, ink, and the oscillating section. While the amount of the ink in an ink tank decreases, he can understand signs that the resonance frequency fs of ink and the oscillating section changes gradually.

[0064] The case where the process in which ink is consumed gradually is detectable in a detail is a case where both the liquids and gases from which a consistency differs mutually exist, and it is concerned with vibration, in the circumference of the oscillating field of an actuator 106 more. While liquids decrease in number, a gas increases the medium on the circumference of an oscillating field of an actuator 106, and in connection with vibration, as ink is consumed gradually. For example, it is the case where an actuator 106 is horizontally arranged to the oil level of ink, and when tink is smaller than tink-max, the medium in connection with vibration of an actuator 106 contains both ink and a gas. Therefore, it is [0065] when the condition of having become below M'max of a formula 4 when it was the area S of the oscillating field of an actuator 106 is expressed with the additional mass of ink and a gas.

M'=M'air+M'ink= rho air*tair/S+rho ink*tink/S (formula 8)

It becomes. Here, M'air is the inertance of air and M'ink is the inertance of ink. rhoair is the consistency of air and rhoink is the consistency of ink. tair is the thickness of the air in connection with vibration, and tink is the thickness of the ink in connection with vibration. When the actuator 106 is arranged almost horizontally to the oil level of ink as liquids decrease in number among the media in connection with the vibration in the circumference of an oscillating field of an actuator 106 and a gas increases, tair increases and tink decreases. By it, M'var decreases gradually and resonance frequency increases gradually. Therefore, the amount of the ink which remains in an ink tank, or the consumption of ink is detectable. In addition, in a formula 7, it is the formula of only the consistency of a liquid because the case of being so small that the consistency of air being disregarded is assumed to the consistency of a liquid.

[0066] When the actuator 106 is arranged almost perpendicularly to the oil level of ink, the media in connection with vibration of an actuator 106 are considered to be the field of only ink, and the equal circuit (not shown) of juxtaposition of the medium in connection with vibration of an actuator 106 with a gaseous field among the oscillating fields of an actuator 106. It is [0067], when the medium in connection with vibration of an actuator 106 sets area of the field of only ink to Sink and the medium in connection with vibration of an actuator 106 sets area of a gaseous field to Sair.

1/M'=1/M'air+1/M'ink=Sair/(rhoair*tair) +Sink/(rhoink*tink) (formula 9)

It becomes.

[0068] In addition, a formula 9 is applied when ink is not held at the cavity of an actuator 106. About the case where ink is held at the cavity of an actuator 106, it is calculable with a formula 7, a formula 8, and a formula 9.

[0069] On the other hand, the oil level of ink will detect an upper location or a bottom location

from the stowed position of an actuator rather than a substrate 178 is thick, namely, depth d of a cavity 162 is deep, and it detects the process in which ink decreases in number gradually in practice, when d uses an actuator with a very small oscillating field as compared with the case of being comparatively close to thickness tink-max of a medium, and the height of a liquid container. When it puts in another way, the existence of the ink in the oscillating field of an actuator will be detected. For example, the curve Y of drawing 3 (A) shows relation with the resonance frequency fs of the amount of the ink in the ink tank in the case of a small circular oscillating field, ink, and the oscillating section. Between the amounts Q of ink before and after the oil level of the ink in an ink tank passes through the stowed position of an actuator, signs that the resonance frequency fs of ink and the oscillating section is changing violently are shown. From this, it is detectable in an ink tank whether ink is carrying out specified quantity survival.
[0070] A diaphragm 176 is contacting a liquid and directly, and since the method of detecting the existence of a liquid using an actuator 106 detects the existence of ink, compared with the approach of calculating the consumption of ink with software, its detection precision is high. Furthermore, although the approach conductivity detects the existence of ink is influenced according to the attaching position to a liquid container, and the class of ink using an electrode, the approach of detecting the existence of a liquid using an actuator 106 is not influenced according to the attaching position to a liquid container, and the class of ink. Furthermore, since the both sides of detection of the existence of a liquid can be considered as an oscillation using the single actuator 106, the number of the sensors attached in a liquid container as compared with the approach of carrying out oscillation and detection of the existence of a liquid using a different sensor can be decreased. Therefore, a liquid container can be manufactured cheaply. Furthermore, it can be [ sound / which an actuator 106 generates working ] quiet by setting the oscillation frequency of the piezo-electric layer 160 as a non-audible field.
[0071] Drawing 3 (B) shows relation with the resonance frequency fs of the consistency of the ink in the curve Y of drawing 3 (A), ink, and the oscillating section. Ink is mentioned as an example of a liquid. Since an addition inertance will become large if an ink consistency becomes high as shown in drawing 3 (B), resonance frequency fs falls. That is, resonance frequency fs changes with classes of ink. Therefore, in case it is re-filled up with ink by measuring resonance frequency fs, it can check whether the ink in which consistencies differed is mixed.
[0072] That is, the ink tank which holds the ink in which classes differ mutually is discriminable.
[0073] Then, even if the liquid in a liquid container is the state of the sky, the conditions which can detect correctly the condition of a liquid when setting up the size and the configuration of a cavity so that a liquid may remain in the cavity 162 of an actuator 106 are explained in full detail. If the condition of a liquid can be detected when the liquid is filled in the cavity 162, an actuator 106 can detect the condition of a liquid, even if it is the case where the liquid is not filled in the cavity 162.
[0074] Resonance frequency fs is a function of Inertance M. Inertance M is the sum of the inertance Mact of the oscillating section, and addition inertance M'. Here, addition inertance M' is related to the condition of a liquid. Addition inertance M' is an amount which shows that the mass of the oscillating section is increasing seemingly according to an operation of the medium near the oscillating section. That is, the increment of the mass of the oscillating section by absorbing a medium seemingly by vibration of the oscillating section is said.
[0075] Therefore, when M'cav is larger than M'max in a formula 4, all the media absorbed seemingly are liquids which remain in a cavity 162. Therefore, it is the same as the condition that the liquid is filled in the liquid container. In this case, since M' does not change, resonance

frequency fs does not change, either. Therefore, an actuator 106 can detect the condition of the liquid in a liquid container.
[0076] On the other hand, when M'cav is smaller than M' max in a formula 4, the medium absorbed seemingly is the gas or vacuum in the liquid which remains in a cavity 162, and a liquid container. Since M' changes unlike the condition that the liquid is filled in the liquid container at this time, resonance frequency fs changes. Therefore, an actuator 106 can detect the condition of the liquid in a liquid container.
[0077] That is, the liquid in a liquid container is the state of the sky, and when a liquid remains in the cavity 162 of an actuator 106, the conditions on which an actuator 106 can detect the condition of a liquid correctly are that M'cav is smaller than M'max. In addition, condition M'max>M'cav to which an actuator 106 can detect the condition of a liquid correctly is not concerned with the configuration of a cavity 162.
[0078] Here, M'cav is the capacity of a cavity 162, and the mass of the liquid of an almost equal capacity. Therefore, an actuator 106 can express the conditions which can detect the condition of a liquid correctly as conditions for the capacity of a cavity 162 from the inequality of M'max>M'cav. For example, it is [0079], when the radius of the opening 161 of the cavity 162 of a circle configuration is set to a and the depth of a cavity 162 is set to d. M'max>rho*d/pi a2 (formula 10)
It comes out. It is [0080] when a formula 10 is developed. a/d>3*pi/8 (formula 11)
The conditions to say are searched for. In addition, when the configuration of a cavity 162 is circular, a formula 10 and a formula 11 are restricted and are materialized. If pia2 in a formula 10 is calculated by replacing it with the area using the formula of M'max when not being circular, the relation between dimensions, such as width of face of a cavity and die length, and the depth can be drawn.
[0081] Therefore, if it is the actuator 106 which has the cavity 162 which are the radius a of the opening 161 which fills a formula 11, and depth [ of a cavity 162 ] d, even if the liquid in a liquid container is the state of the sky and it is the case where a liquid remains in a cavity 162, the condition of a liquid can be detected, without incorrect-operating.
[0082] It can be said that the approach of measuring back EMF generated in an actuator 106 by residual vibration has detected change of an acoustic impedance at least since addition inertance M' also influences an acoustic-impedance property.
[0083] Moreover, according to this example, back EMF which an actuator 106 generates vibration and generates in an actuator 106 by subsequent residual vibration is measured. However, it is not necessarily required for the oscillating section of an actuator 106 to give vibration to a liquid by its vibration by driver voltage. That is, even if the oscillating section does not oscillate itself, the piezo-electric layer 160 bends and deforms by vibrating with the liquid of a certain range in contact with it. This residual vibration makes the piezo-electric layer 160 generate the back EMF electrical potential difference, and transmits that back EMF electrical potential difference to the up electrode 164 and the lower electrode 166. The condition of a medium may be detected by using this phenomenon. For example, it may set to an ink jet recording apparatus, and the condition of an ink tank or the ink of the interior may be detected using vibration around the oscillating section of the actuator generated by vibration by the reciprocating motion of the carriage by the scan of the print head at the time of printing.
[0084] Drawing 4 (A) And drawing 4 (B) shows the wave of the residual vibration of an actuator 106 after vibrating an actuator 106, and the measuring method of residual vibration. the ink in the stowed position level of the actuator 106 in an ink cartridge -- the upper and lower sides of

water level are detectable with frequency change of the residual vibration after an actuator 106 oscillates, and change of the amplitude. Drawing 4 (A) And in drawing 4 (B), an axis of ordinate shows the electrical potential difference of back EMF generated by the residual vibration of an actuator 106, and an axis of abscissa shows time amount. By the residual vibration of an actuator 106, it is drawing 4 R> 4 (A). And as shown in drawing 4 (B), the wave of the analog signal of an electrical potential difference occurs. Next, an analog signal is changed into the digital numeric value corresponding to the frequency of a signal.

[0085] Drawing 4 (A) And in the example shown in drawing 4 (B), the existence of ink is detected by measuring the time amount which four pulses to 8 pulse eye produce from 4 pulse eye of an analog signal.

[0086] More, in a detail, after an actuator 106 oscillates, the count which crosses the predetermined reference voltage set up beforehand from a low-battery side to a high-voltage side is counted. The between from four counts to eight counts is set to High for a digital signal, and the time amount from four counts to eight counts is measured by the predetermined clock pulse.

[0087] Drawing 4 (A) is a wave in case a liquid ink side is in a high order rather than the stowed position level of an actuator 106. On the other hand, drawing 4 (B) is a wave in case there is no ink in the stowed position level of an actuator 106. When drawing 4 R> 4 (A) is compared with drawing 4 (B), in drawing 4 (A), a ******** understands the time amount from four counts to eight counts from drawing 4 (B). A paraphrase changes the time amount from four counts to eight counts by the existence of ink. The consumption condition of ink is detectable using a difference of this time amount. After vibration of an actuator 106 is stabilized, it counts for beginning measurement from 4 count eye of an analog wave. What it was presupposed that it is from 4 count eye is a mere example, and may count from the count of arbitration. Here, the signal from 4 count eye to 8 count eye is detected, and the time amount from 4 count eye to 8 count eye is measured by the predetermined clock pulse. It asks for resonance frequency by it. As for a clock pulse, it is desirable that it is the pulse of a clock equal to the clock for controlling the semiconductor memory attached in an ink cartridge. In addition, there is no need of measuring the time amount to 8 count eye, and it may be counted to the count of arbitration. In drawing 4 , although the time amount from 4 count eye to 8 count eye is measured, according to the circuitry which detects a frequency, the time amount in a different counting interval may be detected.

[0088] For example, when fluctuation of the amplitude of a peak is small, in order the quality of ink is stable, and to gather the rate of detection, you may ask for resonance frequency by detecting the time amount from 4 count eye to 6 count eye. Moreover, the quality of ink is unstable, and when fluctuation of the amplitude of a pulse is large, in order to detect residual vibration correctly, the time amount from 4 count eye to 12 count eye may be detected.

[0089] Moreover, the wave number of the voltage waveform of back EMF within a predetermined period may be counted as other examples (not shown). It can ask for resonance frequency also by this approach. More, in a detail, after an actuator 106 oscillates, only a predetermined period sets a digital signal to High, and the count which crosses predetermined reference voltage from a low-battery side to a high-voltage side is counted. The existence of ink is detectable by measuring the number of counts.

[0090] Furthermore, the back EMF wave amplitudes differ by the case where there are not a case where ink is filled in the ink cartridge, and ink into an ink cartridge so that drawing 4 (A) and drawing 4 (B) may be compared and understood. Therefore, the consumption condition of the ink in an ink cartridge may be detected also by measuring the back EMF wave amplitude,

without asking for resonance frequency. Top-most vertices and drawing 4 (B) of the back EMF wave [ detail ] of drawing 4 R> 4 (A) more Reference voltage is set up between the top-most vertices of the back EMF wave. When a digital signal is set to High at predetermined time and the back EMF wave crosses reference voltage after the actuator 106 oscillated, it is judged that there is no ink. When the back EMF wave does not cross reference voltage, it is judged that there is ink.

[0091] Drawing 5 shows the manufacture approach of an actuator 106. Two or more actuators 106 (the example of drawing 5 four pieces) are formed in one. The actuator 106 shown in drawing 6 is manufactured by cutting the one moldings of two or more actuators shown in drawing 5 in each actuator 106. When each piezoelectric device of two or more really shown [ in drawing 5 ] fabricated actuators 106 is circular, the actuator 106 shown in drawing 1 can be manufactured by really cutting a moldings in each actuator 106. By forming two or more actuators 106 in one, two or more actuators 106 can be efficiently manufactured to coincidence, and the handling at the time of conveyance becomes easy.

[0092] An actuator 106 has sheet metal or a diaphragm 176, a substrate 178, an elastic wave generating means or a piezoelectric device 174, a terminal formation member or the up electrode terminal 168 and a terminal formation member, or the lower electrode terminal 170. A piezoelectric device 174 contains a piezo-electric diaphragm or the piezo-electric layer 160, an upper electrode or the up electrode 164 and a bottom electrode, or the lower electrode 166. A diaphragm 176 is formed in the top face of a substrate 178, and the lower electrode 166 is formed in the top face of a diaphragm 176. The piezo-electric layer 160 is formed in the top face of the lower electrode 166, and the up electrode 164 is formed in the top face of the piezo-electric layer 160. Therefore, of the principal part of the up electrode 164, and the principal part of the lower electrode 166, the principal part of the piezo-electric layer 160 is formed so that it may be inserted from the upper and lower sides.

[0093] The piezoelectric device 174 of plurality (the example of drawing 5 four pieces) is formed on the diaphragm 176. The lower electrode 166 is formed in the front face of a diaphragm 176, the piezo-electric layer 160 is formed in the front face of the lower electrode 166, and the up electrode 164 is formed in the top face of the piezo-electric layer 160. The up electrode terminal 168 and the lower electrode terminal 170 are formed in the edge of the up electrode 164 and the lower electrode 166. Four actuators 106 are cut separately, respectively and are used according to an individual.

[0094] As for drawing 6 , a piezoelectric device shows some cross sections of the rectangular actuator 106.

[0095] Drawing 7 shows the cross section of the whole actuator 106 shown in drawing 6 . Through tube 178a is formed in the piezoelectric device 174 of a substrate 178, and the field which counters. The closure of the through tube 178a is carried out by the diaphragm 176. A diaphragm 176 is equipped with electric insulation, such as an alumina and an oxidization zirconia, and is formed with the ingredient in which elastic deformation is possible. The piezoelectric device 174 is formed on the diaphragm 176 so that it may counter with through tube 178a. The lower electrode 166 is formed in the front face of a diaphragm 176 so that it may extend from the field of through tube 178a to the left in an one direction and drawing 7 . The up electrode 164 is formed in the front face of the piezo-electric layer 160 so that it may extend in the method of the right in drawing 7 in the direction opposite to a lower electrode from the field of through tube 178a. The up electrode terminal 168 and the lower electrode terminal 170 are formed in the top face of an auxiliary electrode 172 and the lower electrode 166, respectively.

The lower electrode terminal 170 contacts the lower electrode 166 electrically, and the up electrode terminal 168 contacts the up electrode 164 electrically through an auxiliary electrode 172, and it delivers the signal between a piezoelectric device and the exterior of an actuator 106. The up electrode terminal 168 and the lower electrode terminal 170 have the height more than the height of the piezoelectric device which doubled the electrode and the piezo-electric layer.
[0096] Drawing 8 shows the manufacture approach of the actuator 106 shown in drawing 5 . First, a press or laser processing is used for a green sheet 940, and through tube 940a is punched. A green sheet 940 serves as a substrate 178 after baking. A green sheet 940 is formed with ingredients, such as a ceramic. Next, the laminating of the green sheet 941 is carried out to the front face of a green sheet 940. A green sheet 941 serves as a diaphragm 176 after baking. A green sheet 941 is formed with ingredients, such as an oxidization zirconia. Next, sequential formation of a conductive layer 942, the piezo-electric layer 160, and the conductive layer 944 is carried out by approaches, such as pressure membrane printing, on the front face of a green sheet 941. A conductive layer 942 serves as the lower electrode 166 behind, and a conductive layer 944 serves as the up electrode 164 behind. Next, the formed green sheet 940, a green sheet 941, a conductive layer 942, the piezo-electric layer 160, and a conductive layer 944 are dried and calcinated. Spacing members 947 and 948 carry out bottom raising of the height of the up electrode terminal 168 and the lower electrode terminal 170, and make it higher than a piezoelectric device. Spacing members 947 and 948 carry out the laminating of printing or the green sheet, and form green sheets 940 and 941 and this ingredient. Since there are few ingredients of the up electrode terminal 168 which is noble metals, and the lower electrode terminal 170, it ends upwards by this spacing member 947,948 and thickness of the up electrode terminal 168 and the lower electrode terminal 170 can be made thin, the up electrode terminal 168 and the lower electrode terminal 170 can be printed with a sufficient precision, and it can consider as the height stabilized further.
[0097] If connection 944' with a conductive layer 944 and spacing members 947 and 948 are formed in coincidence at the time of formation of a conductive layer 942, the up electrode terminal 168 and the lower electrode terminal 170 can be formed easily, or it can fix firmly. Finally, the up electrode terminal 168 and the lower electrode terminal 170 are formed in the edge field of a conductive layer 942 and a conductive layer 944. In case the up electrode terminal 168 and the lower electrode terminal 170 are formed, it forms so that the up electrode terminal 168 and the lower electrode terminal 170 may be electrically connected to the piezo-electric layer 160.
[0098] Drawing 9 shows the operation gestalt of further others of the ink cartridge to which this invention is applied. Drawing 9 (A) is the sectional view of the pars basilaris ossis occipitalis of the ink cartridge by this operation gestalt. The ink cartridge of this operation gestalt has through tube 1c in base 1a of a container 1 which holds ink. The pars basilaris ossis occipitalis of through tube 1c is closed by the actuator 650, and forms an ink reservoir.
[0099] Drawing 9 (B) shows the actuator 650 shown in drawing 9 (A), and the detailed cross section of through tube 1c. Drawing 9 R> 9 (C) shows the flat surface of the actuator 650 shown in drawing 9 (B), and through tube 1c. An actuator 650 has the piezoelectric device 73 fixed to the diaphragm 72 and the diaphragm 72. An actuator 650 is fixed to the base of a container 1 so that a piezoelectric device 73 may counter through tube 1c through a diaphragm 72 and a substrate 71. Elastic deformation is possible for a diaphragm 72, and it is equipped with ink-proof nature.
[0100] Depending on the amount of ink of a container 1, the amplitude and frequency of back

EMF which are generated by the residual vibration of a piezoelectric device 73 and a diaphragm 72 change. Through tube 1c is formed in the location which counters an actuator 650, and the ink of the minimum constant rate is secured to through tube 1c. Therefore, the ink end of a container 1 is certainly detectable by measuring beforehand the property of vibration of the actuator 650 decided by the amount of ink secured to through tube 1c.

[0101] Drawing 10 shows other operation gestalten of through tube 1c. In each of drawing 10 (A), (B), and (C), the condition that the chart on the left does not have Ink K in through tube 1c is shown, and right-hand side drawing shows the condition that Ink K remained in through tube 1c. In the operation gestalt of drawing 9 , the side face of through tube 1c is formed as a perpendicular wall. In drawing 10 (A), 1d of side faces of through tube 1c is slanting in the vertical direction, and it is expanded and opened outside. In drawing 10 (B), the level difference sections 1e and 1f are formed in the side face of through tube 1c. 1f of level difference sections which are up is larger than level difference section 1e which exists caudad. In drawing 10 (C), through tube 1c has 1g of slots which extend in the direction of the ink feed hopper 2 which is easy to discharge Ink K, i.e., the direction.

[0102] Drawing 10 (A) According to the configuration of through tube 1c shown in - (C), the amount of the ink K of an ink reservoir can be lessened. Therefore, since the oscillation characteristic of the ink and the actuator 650 at the time since M'cav explained by drawing 1 and drawing 2 can be made small as compared with M'max can be greatly changed with the case where the ink K of the amount which can be printed in a container 1 remains, an ink end can be detected more certainly.

[0103] Drawing 11 is the perspective view showing other operation gestalten of an actuator. An actuator 660 has packing 76 outside through tube 1c of the substrate which constitutes an actuator 660, or the attachment plate 78. The caulking hole 77 is formed in the periphery of an actuator 660. An actuator 660 is fixed to a container 1 with caulking through the caulking hole 77.

[0104] Drawing 12 (A) and (B) are the perspective views showing the operation gestalt of further others of an actuator. An actuator 670 is equipped with the crevice formation substrate 80 and a piezoelectric device 82 in this operation gestalt. A crevice 81 is formed in one field of the crevice formation substrate 80 of technique, such as etching, and a piezoelectric device 82 is attached in the field of another side. The pars basilaris ossis occipitalis of a crevice 81 acts as an oscillating field among the crevice formation substrates 80. Therefore, the oscillating field of an actuator 670 is specified by the periphery of a crevice 81. Moreover, an actuator 670 is similar with the structure where the substrate 178 and the diaphragm 176 were formed as one among the actuators 106 by the example of drawing 1 . Therefore, in case an ink cartridge is manufactured, a production process can be shortened, and cost is reduced. An actuator 670 is size in which embedding is possible to through tube 1c prepared in the container 1. By it, a crevice 81 can act also as a cavity. In addition, like the actuator 670 by the example of drawing 12 , the actuator 106 by the example of drawing 1 may be formed in through tube 1c so that embedding may be possible.

[0105] Drawing 13 is the perspective view showing the configuration which attached the actuator 106 and was really formed as a module object 100. The predetermined part of the container 1 of an ink cartridge is equipped with the module object 100. By [ in liquid ink ] detecting change of an acoustic impedance at least, the module object 100 is constituted so that the consumption condition of the liquid in a container 1 may be detected. The module object 100 of this operation gestalt has the liquid-container attachment section 101 for attaching an actuator

106 in a container 1. The liquid-container attachment section 101 has structure with which the flat surface carried the cylinder section 116 which held the actuator 106 oscillated with a driving signal on the rectangular pedestal 102 mostly. Since it is constituted so that the actuator 106 of the module object 100 cannot contact from the outside when an ink cartridge is equipped with the module object 100, an actuator 106 can be protected from external contact. In addition, the radius of circle is attached, and in case the hole formed in the ink cartridge is equipped, it is easy to insert in the tip side edge of the cylinder section 116.

[0106] Drawing 14 is the exploded view showing the configuration of the module object 100 shown in drawing 13 . The module object 100 contains the liquid-container attachment section 101 which consists of resin, and the piezoelectric device applied part 105 which has a plate 110 and a crevice 113. Furthermore, the module object 100 has reed wires 104a and 104b, an actuator 106, and a film 108. Preferably, a plate 110 is formed from ingredients which cannot rust easily, such as stainless steel or a stainless alloy. Opening 114 is formed in a core so that the cylinder section 116 and the pedestal 102 which are included in the liquid-container attachment section 101 can hold reed wires 104a and 104b, and a crevice 113 is formed so that an actuator 106, a film 108, and a plate 110 can be held. An actuator 106 is joined to a plate 110 through a film 108, and a plate 110 and an actuator 106 are fixed to the liquid-container attachment section 101. Therefore, reed wires 104a and 104b, an actuator 106, a film 108, and a plate 110 are attached in the liquid-container attachment section 101 as one. Reed wires 104a and 104b combine with the up electrode of an actuator 106, and a lower electrode, respectively, transmit a driving signal to a piezo-electric layer, and, on the other hand, transmit the signal of the resonance frequency which the actuator 106 detected to a recording device etc. An actuator 106 is temporarily oscillated based on the driving signal transmitted from reed wires 104a and 104b. Residual vibration of the actuator 106 is carried out after an oscillation, and it generates back EMF by the vibration. At this time, the resonance frequency corresponding to the consumption condition of the liquid in a liquid container is detectable by detecting the period of vibration of the back EMF wave. a film 108 -- an actuator 106 and a plate 110 -- pasting up -- an actuator -- liquid -- it is made dense. As for a film 108, it is desirable to form with polyolefine etc. and to paste up by thermal melting arrival. a film 108 -- an actuator 106 and a plate 110 -- pasting up -- an actuator -- liquid -- it is made dense. As for a film 108, it is desirable to form with polyolefine and to paste up by thermal melting arrival. By pasting up an actuator 106 and a plate 110 in the shape of a field with a film 108, and fixing, dispersion by the location of adhesion is lost and any parts other than the oscillating section do not vibrate. Therefore, change of the resonance frequency of the back before pasting up an actuator 106 on a plate 110 is small.

[0107] A plate 110 is a circle configuration and the opening 114 of a pedestal 102 is formed in the shape of a cylinder. The actuator 106 and the film 108 are formed in the shape of a rectangle. A reed wire 104, an actuator 106, a film 108, and a plate 110 are good also as removable to a pedestal 102. A pedestal 102, the reed wire 104, the actuator 106, the film 108, and the plate 110 are arranged to the medial axis of the module object 100 at the symmetry. furthermore, the core of a pedestal 102, an actuator 106, a film 108, and a plate 110 -- the module object 100 -- it is mostly arranged on the medial axis.

[0108] The area of the opening 114 of a pedestal 102 is formed more greatly than the area of the oscillating field of an actuator 106. The through tube 112 is formed in the location which faces the oscillating section of an actuator 106 at the core of a plate 110. As shown in drawing 1 and drawing 2 , a cavity 162 is formed in an actuator 106, and both a through tube 112 and the cavity 162 form an ink reservoir. In order to lessen effect of residual ink, compared with the path of a

through tube 112, the small thing of the thickness of a plate 110 is desirable. For example, as for the depth of a through tube 112, it is desirable that it is 1/3 or less magnitude of the path. a through tube 112 is the symmetry to the medial axis of the module object 100 -- it is the configuration of a perfect circle mostly. Moreover, the area of a through tube 112 is larger than the opening area of the cavity 162 of an actuator 106. The periphery of the cross section of a through tube 112 may be a taper configuration, and a step configuration is sufficient as it. The flank of a container 1, the upper part, or a pars basilaris ossis occipitalis is equipped with the module object 100 so that a through tube 112 may turn to the inside of a container 1. If ink is consumed and the ink of the actuator 106 circumference is lost, since the resonance frequency of an actuator 106 will change a lot, at least the water of ink can detect change.

[0109] Drawing 15 is the perspective view showing other operation gestalten of a module object. As for the module object 400 of this operation gestalt, the piezoelectric device applied part 405 is formed in the liquid-container attachment section 401. As for the liquid-container attachment section 401, the cylinder-like cylinder section 403 is mostly formed for the flat surface on the pedestal 402 on Kakumaru's square. Furthermore, the piezoelectric device applied part 405 includes the tabular element 406 and crevice 413 which were stood on the cylinder section 403. An actuator 106 is arranged in the crevice 413 established in the side face of the tabular element 406. In addition, the tip of the tabular element 406 is beveled by the predetermined include angle, and in case the hole formed in the ink cartridge is equipped, it is easy to insert it in.

[0110] Drawing 16 is the decomposition perspective view showing the configuration of the module object 400 shown in drawing 15 . The module object 400 as well as the module object 100 shown in drawing 13 contains the liquid-container attachment section 401 and the piezoelectric device applied part 405. The liquid-container attachment section 401 has a pedestal 402 and the cylinder section 403, and the piezoelectric device applied part 405 has the tabular element 406 and a crevice 413. It is joined to a plate 410 and an actuator 106 is fixed to a crevice 413. The module object 400 has further reed wires 404a and 404b, an actuator 106, and a film 408.

[0111] According to this operation gestalt, a plate 410 is a rectangle-like and the opening 414 prepared in the tabular element 406 is formed in the shape of a rectangle. Reed wires 404a and 404b, an actuator 106, a film 408, and a plate 410 may be constituted as removable to a pedestal 402. An actuator 106, a film 408, and a plate 410 pass along the core of opening 414, and are arranged at the symmetry to the medial axis prolonged in the direction of a vertical to the flat surface of opening 414. furthermore, the core of an actuator 406, a film 408, and a plate 410 -- opening 414 -- it is mostly arranged on the medial axis.

[0112] The area of the through tube 412 prepared in the core of a plate 410 is formed more greatly than the area of opening of the cavity 162 of an actuator 106. Both the cavities 162 and through tubes 412 of an actuator 106 form an ink reservoir. The thickness of a plate 410 is small compared with the path of a through tube 412, for example, it is desirable to set it as 1/3 or less magnitude of the path of a through tube 412. a through tube 412 is the symmetry to the medial axis of the module object 400 -- it is the configuration of a perfect circle mostly. The periphery of the cross section of a through tube 412 may be a taper configuration, and a step configuration is sufficient as it. The pars basilaris ossis occipitalis of a container 1 can be equipped with the module object 400 so that a through tube 412 may be arranged inside a container 1. Since it is arranged in a container 1 so that an actuator 106 may be prolonged perpendicularly, a setup at the time of an ink end is easily changeable by changing the height which changes the height of a pedestal 402 and by which an actuator 106 is arranged in a container 1.

[0113] Drawing 17 shows the operation gestalt of further others of a module object. The module object 500 of drawing 17 as well as the module object 100 shown in drawing 13 contains the liquid-container attachment section 501 which has a pedestal 502 and the cylinder section 503. Moreover, the module object 500 has further reed wires 504a and 504b, an actuator 106, a film 508, and a plate 510. Opening 514 is formed in a core so that the pedestal 502 included in the liquid-container attachment section 501 can hold reed wires 504a and 504b, and a crevice 513 is formed so that an actuator 106, a film 508, and a plate 510 can be held. PUAKUCHUETA 106 is fixed to the piezoelectric device applied part 505 through a plate 510. Therefore, reed wires 504a and 504b, an actuator 106, a film 508, and a plate 510 are attached in the liquid-container attachment section 501 as one. As for the module object 500 of this operation gestalt, the cylinder section 503 with a top face slanting in the vertical direction is mostly formed for the flat surface on the pedestal on Kakumaru's square. The actuator 106 is arranged on the crevice 513 aslant prepared in the vertical direction of the top face of the cylinder section 503.
[0114] The tip of the module object 500 inclines and the inclined plane is equipped with the actuator 106. Therefore, if the pars basilaris ossis occipitalis or flank of a container 1 is equipped with the module object 500, an actuator 106 inclines to the vertical direction of a container 1. As for whenever [ tilt-angle / of the tip of the module object 500 ], it is desirable to consider as for about 30 to 60 degrees in view of detectability ability.
[0115] The pars basilaris ossis occipitalis or flank of a container 1 is equipped with the module object 500 so that an actuator 106 may be arranged in a container 1. When the flank of a container 1 is equipped with the module object 500, it is attached in a container 1, an actuator 106 inclining so that a container 1 top, bottom, or width side may be turned to. It is desirable that it is attached in a container 1 on the other hand, an actuator 106 inclining so that the ink feed hopper side of a container 1 may be turned to when the pars basilaris ossis occipitalis of a container 1 is equipped with the module object 500.
[0116] Drawing 18 is a sectional view near the pars basilaris ossis occipitalis of the ink container when equipping a container 1 with the module object 100 shown in drawing 13 . It is equipped with the module object 100 so that the side attachment wall of a container 1 may be penetrated. O ring 365 is formed in the plane of composition of the side attachment wall of a container 1, and the module object 100, and **** of the module object 100 and a container 1 is maintained at it. It is desirable to have the cylinder section which the module object 100 explained that a seal is made with an O ring by drawing 13 . By the tip of the module object 100 being inserted in the interior of a container 1, the ink in a container 1 contacts an actuator 106 through the through tube 112 of a plate 110. Since the resonance frequency of the residual vibration of an actuator 106 changes with a liquid or gases, the perimeter of the oscillating section of an actuator 106 can detect the consumption condition of ink using the module object 100. Moreover, a container 1 may be equipped with the module objects 700A, 700B, 750A, and 750B shown in the module object 400 shown not only in the module object 100 but in drawing 15 , the module object 500 shown in drawing 17 R> 7 or drawing 19 , and drawing 20 , and the mold structure 600, and the existence of ink may be detected.
[0117] Drawing 19 shows the operation gestalt of further others of the module object 100. Module object 750A of drawing 19 (A) has an actuator 106 and a pedestal 360. The container 1 is equipped with module object 750A so that a front face may turn into an inside of the side attachment wall of a container 1, and the same field. An actuator 106 contains the piezo-electric layer 160, the up electrode 164, the lower electrode 166, and a diaphragm 176. The lower electrode 166 is formed in the top face of a diaphragm 176. The piezo-electric layer 160 is

formed in the top face of the lower electrode 166, and the up electrode 164 is formed in the top face of the piezo-electric layer 160. Therefore, the piezo-electric layer 160 is formed so that it may be inserted from the upper and lower sides with the up electrode 164 and the lower electrode 166. The piezo-electric layer 160, the up electrode 164, and the lower electrode 166 form a piezoelectric device. A piezoelectric device is formed on a diaphragm 176. A piezoelectric device and the oscillating field of a diaphragm 176 are the oscillating sections in which an actuator actually vibrates. The through tube 385 is formed in the side attachment wall of a container 1. Therefore, ink contacts a diaphragm 176 through the through tube 385 of a container 1.

[0118] Next, the actuation of module object 750A shown in drawing 19 (A) is explained. The up electrode 164 and the lower electrode 166 transmit a driving signal to the piezo-electric layer 160, and transmit the signal of the resonance frequency which the piezo-electric layer 160 detected to a recording device. It oscillates with the driving signal transmitted with the up electrode 164 and the lower electrode 166, and residual vibration of the piezo-electric layer 160 is carried out. The piezo-electric layer 160 generates back EMF by this residual vibration. The period of vibration of the back EMF wave is counted, and the existence of ink can be detected by detecting the resonance frequency in the time. A container 1 is equipped only with a diaphragm 176 so that module object 750A may contact the ink in the ink container 1 in the field where an actuator 106 is opposite to the piezoelectric-device side of the oscillating section of an actuator 106, i.e., drawing 19 , (A). Module object 750A of drawing 19 (A) becomes unnecessary [ the embedding to the module object 100 of the electrode of reed wires 104a, 104b, 404a, 404b, 504a and 504b shown in drawing 17 from drawing 13 ]. Therefore, a forming cycle is simplified. Furthermore, it becomes exchangeable [ module object 750A ], and becomes recyclable. Furthermore, since the actuator 106 is protected by the pedestal 360, it can protect an actuator 106 from contact outside.

[0119] Drawing 19 (B) shows the operation gestalt of further others of module object 750B. Module object 750B of drawing 19 (B) has an actuator 106 and a pedestal 360. The container 1 is equipped with module object 750B so that a front face may turn into an inside of the side attachment wall of a container 1, and the same field. An actuator 106 contains the piezo-electric layer 160, the up electrode 164, the lower electrode 166, and a diaphragm 176. The lower electrode 166 is formed in the top face of a diaphragm 176. The piezo-electric layer 160 is formed in the top face of the lower electrode 166, and the up electrode 164 is formed in the top face of the piezo-electric layer 160. Therefore, the piezo-electric layer 160 is formed so that it may be inserted from the upper and lower sides with the up electrode 164 and the lower electrode 166. The piezo-electric layer 160, the up electrode 164, and the lower electrode 166 form a piezoelectric device. A piezoelectric device is formed on a diaphragm 176. A piezoelectric device and the oscillating field of a diaphragm 176 are the oscillating sections in which an actuator actually vibrates. The thin wall 380 is formed in the side attachment wall of a container 1. A container 1 is equipped only with a diaphragm 176 so that module object 750B may contact the thin wall 380 of the ink container 1 in the field where an actuator 106 is opposite to the piezoelectric-device side of the oscillating section of an actuator 106, i.e., drawing 19 , (B). Therefore, residual vibration of the oscillating section of an actuator 106 is carried out with the thin wall 380.

[0120] Next, the actuation of module object 750B shown in drawing 19 (B) is explained. The up electrode 164 and the lower electrode 166 transmit a driving signal to the piezo-electric layer 160, and transmit the signal of the resonance frequency which the piezo-electric layer 160

detected to a recording device. It oscillates with the driving signal transmitted with the up electrode 164 and the lower electrode 166, and the piezo-electric layer 160 vibrates with a resonant period. Since the thin wall 380 of a container 1 is contacted, a diaphragm 176 carries out residual vibration of the oscillating section of an actuator 106 with the thin wall 380. Since the inside side of the container 1 of the thin wall 380 contacts ink, in case an actuator 106 carries out residual vibration with the thin wall 380, the resonance frequency and the amplitude of this residual vibration change with ink residues. The piezo-electric layer 160 generates back EMF by this residual vibration. The period of vibration of the back EMF wave can be counted, and an ink residue can be detected by detecting the resonance frequency at that time.

[0121] Module object 750B of drawing 19 (B) becomes unnecessary [ the embedding to the module object 100 of the electrode of reed wires 104a, 104b, 404a, 404b, 504a, and 504b shown in drawing 17 from drawing 13 ]. Therefore, a forming cycle is simplified. Furthermore, it becomes exchangeable [ module object 750B ], and becomes recyclable. Furthermore, since the actuator 106 is protected by the pedestal 360, it can protect an actuator 106 from contact outside.

[0122] Drawing 20 (A) shows the sectional view of the ink container when equipping a container 1 with module object 700B. In this example, module object 700B is used as one of the attachment structures. The container 1 is equipped with module object 700B as the liquid-container attachment section 360 projects inside a container 1. A through tube 370 is formed in the attachment plate 350, and the oscillating section of a through tube 370 and an actuator 106 faces. Furthermore, a hole 382 is formed in the bottom wall of module object 700B, and the piezoelectric device applied part 363 is formed. As an actuator 106 closes one side of a hole 382, it is arranged. Therefore, ink contacts a diaphragm 176 through the hole 382 of the piezoelectric device applied part 363, and the through tube 370 of the attachment plate 350. Both the hole 382 of the piezoelectric device applied part 363 and the through tube 370 of the attachment plate 350 form an ink reservoir. The piezoelectric device applied part 363 and the actuator 106 are being fixed by the attachment plate 350 and the film member. The sealing structure 372 is formed in the connection of the liquid-container attachment section 360 and a container 1. The sealing structure 372 may be formed with reversible ingredients, such as synthetic resin, and may be formed with an O ring. although module object 700B of drawing 20 (A) and a container 1 are another objects -- drawing 20 (B) -- the piezoelectric device applied part of module object 700B may consist of some containers 1 like.

[0123] Module object 700B of drawing 20 (A) becomes unnecessary [ the embedding to the module object of a reed wire shown in drawing 17 from drawing 13 ]. Therefore, a forming cycle is simplified. Furthermore, it becomes exchangeable [ module object 700B ], and becomes recyclable.

[0124] In case an ink cartridge shakes, an actuator 106 may incorrect-operate because the ink which ink adhered to the top face or side face of a container 1, and has hung down from the top face or side face of a container 1 contacts an actuator 106. However, since the liquid-container attachment section 360 has projected module object 700B inside the container 1, an actuator 106 does not incorrect-operate in the ink which has hung down from the top face and side face of a container 1.

[0125] Moreover, in the example of drawing 20 (A), a container 1 is equipped with some of diaphragms 176 and attachment plates 350 so that the ink in a container 1 may be contacted. In the example of drawing 20 (A), the embedding to the module object of the electrode of reed wires 104a, 104b, 404a, 404b, 504a, and 504b shown in drawing 17 from drawing 13 becomes unnecessary. Therefore, a forming cycle is simplified. Furthermore, it becomes exchangeable [

an actuator 106 ] and becomes recyclable.
[0126] Drawing 20 (B) shows the sectional view of an ink container as an example when equipping a container 1 with an actuator 106. In the ink cartridge by the example of drawing 20 (B), the protection member 361 is attached in the container 1 as another object in the actuator 106. Therefore, although the protection member 361 and the actuator 106 are not united as a module, they are one side, and the protection member 361 can protect them so that a user's hand cannot be touched at an actuator 106. The hole 380 prepared in the front face of an actuator 106 is arranged by the side attachment wall of a container 1. An actuator 106 contains the piezo-electric layer 160, the up electrode 164, the lower electrode 166, a diaphragm 176, and the attachment plate 350. A diaphragm 176 is formed in the top face of the attachment plate 350, and the lower electrode 166 is formed in the top face of a diaphragm 176. The piezo-electric layer 160 is formed in the top face of the lower electrode 166, and the up electrode 164 is formed in the top face of the piezo-electric layer 160. Therefore, the principal part of the piezo-electric layer 160 is formed so that it may be inserted by the principal part of the up electrode 164, and the principal part of the lower electrode 166 from the upper and lower sides. The circular part which is each principal part of the piezo-electric layer 160, the up electrode 164, and the lower electrode 166 forms a piezoelectric device. A piezoelectric device is formed on a diaphragm 176. A piezoelectric device and the oscillating field of a diaphragm 176 are the oscillating sections in which an actuator actually vibrates. The through tube 370 is formed in the attachment plate 350. Furthermore, the hole 380 is formed in the side attachment wall of a container 1. Therefore, ink contacts a diaphragm 176 through the hole 380 of a container 1, and the through tube 370 of the attachment plate 350. Both the hole 380 of a container 1 and the through tube 370 of the attachment plate 350 form an ink reservoir. Moreover, in the example of drawing 20 (B), since the actuator 106 is protected by the protection member 361, it can protect an actuator 106 from contact outside.
[0127] In addition, it may replace with drawing 20 (A) and the attachment plate 350 in the example of (B), and the substrate 178 of drawing 1 may be used.
[0128] Drawing 20 (C) shows an operation gestalt equipped with the mold structure 600 containing an actuator 106. In this example, the mold structure 600 is used as one of the attachment structures. The mold structure 600 has an actuator 106 and the mold section 364. An actuator 106 and the mold section 364 are fabricated by one. The mold section 364 is fabricated with reversible ingredients, such as silicon resin. The mold section 364 has a reed wire 362 inside. The mold section 364 is formed so that it may have two guide pegs prolonged from an actuator 106. the mold section 364 -- the mold section 364 and a container 1 -- liquid -- since it fixes densely, the edge of two guide pegs of the mold section 364 is formed in the shape of a semi-sphere. A container 1 is equipped with the mold section 364 so that an actuator 106 may project inside a container 1, and the oscillating section of an actuator 106 contacts the ink in a container 1. The up electrode 164, the piezo-electric layer 160, and the lower electrode 166 of an actuator 106 are protected from ink by the mold section 364.
[0129] For the mold structure 600 of drawing 20 (C), since the sealing structure 372 is unnecessary between the mold section 364 and a container 1, ink is a pile to the leakage from a container 1. Moreover, since it is the gestalt in which the mold structure 600 does not project from the exterior of a container 1, an actuator 106 can be protected from contact outside. In case an ink cartridge shakes, an actuator 106 may incorrect-operate because the ink which ink was attached to the top face or side face of a container 1, and has hung down from the top face or side face of a container 1 contacts an actuator 106. Since the mold section 364 has projected the mold

structure 600 inside the container 1, an actuator 106 does not incorrect-operate in the ink which has hung down from the top face and side face of a container 1.
[0130] Drawing 21 shows the operation gestalt of the ink cartridge and ink jet recording device using the actuator 106 shown in drawing 1 . The ink jet recording device which has two or more ink induction 182 and electrode holders 184 corresponding to each ink cartridge 180 is equipped with two or more ink cartridges 180. Two or more ink cartridges 180 hold the ink of a class different, respectively, for example, a color. Each base of two or more ink cartridges 180 is equipped with the actuator 106 which is a means to detect an acoustic impedance at least. By equipping an ink cartridge 180 with an actuator 106, the ink residue in an ink cartridge 180 is detectable.
[0131] Drawing 22 shows the detail of the head section circumference of an ink jet recording device. An ink jet recording device has the ink induction 182, an electrode holder 184, the head plate 186, and a nozzle plate 188. Two or more formation of the nozzle 190 which injects ink is carried out at the nozzle plate 188. The ink induction 182 has the air supply opening 181 and the ink inlet 183. The air supply opening 181 supplies air to an ink cartridge 180. The ink inlet 183 introduces ink from an ink cartridge 180. An ink cartridge 180 has an air induction inlet 185 and the ink feed hopper 187. An air induction inlet 185 introduces air from the air supply opening 181 of the ink induction 182. The ink feed hopper 187 supplies ink to the ink inlet 183 of the ink induction 182. When an ink cartridge 180 introduces air from the ink induction 182, supply of the ink from the ink cartridge 180 to the ink induction 182 is urged. An electrode holder 184 opens for free passage the ink supplied through the ink induction 182 from the ink cartridge 180 on the head plate 186.
[0132] Drawing 23 shows other operation gestalten of an ink cartridge 180 shown in drawing 20 . Base 194a by which ink cartridge 180A of drawing 23 (A) was aslant formed in the vertical direction is equipped with the actuator 106. Inside the ink container 194 of an ink cartridge 180, the breaking-the-water wall 192 is formed in the actuator 106 of predetermined height, and the faced location from the internal base of the ink container 194. Since it is aslant equipped with the actuator 106 to the vertical direction of the ink container 194, it becomes the ****** fitness of ink.
[0133] The gap filled with ink is formed between an actuator 106 and the breaking-the-water wall 192. Moreover, spacing of the breaking-the-water wall 192 and an actuator 106 is vacated for extent with which ink is not held according to the capillary tube force. When the ink container 194 rolls, the wave of ink occurs in the ink container 194 interior by rolling, a gas and air bubbles are detected by the impact with an actuator 106, and an actuator 106 may incorrect-operate by it. By establishing the breaking-the-water wall 192, the wave of the ink of the actuator 106 neighborhood can be prevented and incorrect actuation of an actuator 106 can be prevented.
[0134] It is equipped with the actuator 106 of ink cartridge 180B of drawing 23 (B) on the side attachment wall of the feed hopper of the ink container 194. As long as it is near the ink feed hopper 187, the side attachment wall or base of the ink container 194 may be equipped with an actuator 106. Moreover, as for an actuator 106, it is desirable that the core of the cross direction of the ink container 194 is equipped. Since ink passes the ink feed hopper 187 and is supplied outside, ink and an actuator 106 contact certainly to an ink near end time by forming an actuator 106 near the ink feed hopper 187. Therefore, an actuator 106 can detect the time of an ink near end certainly.
[0135] Furthermore, by forming an actuator 106 near the ink feed hopper 187, in case the cartridge holder on carriage is equipped with an ink container, positioning with the actuator 106

on an ink container and the contact on carriage becomes certain. In connection on an ink container and carriage, positive association with an ink feed hopper and a supply needle is the most important for the reason. It is because its tip of a supply needle is hurt, or a damage will be given to sealing structures, such as an O ring, and ink will begin to leak, if there is a gap. In order to prevent such a trouble, the ink jet printer usually has the special structure which can do exact alignment, when mounting an ink container on carriage. Therefore, by arranging an actuator near the feed hopper, the alignment of an actuator also becomes a positive thing at coincidence. Furthermore, alignment can be more certainly carried out by equipping the core of the cross direction of the ink container 194 with an actuator 106. When an ink container carries out axial rocking a core [ a crosswise center line ] at the time of wearing to a holder, it is because there are few the shakes.

[0136] Drawing 24 shows the operation gestalt of further others of an ink cartridge 180. The sectional view which expanded side-attachment-wall 194b of ink cartridge 180C which showed drawing 24 (A) in the sectional view of ink cartridge 180C, and showed drawing 24 (B) to drawing 24 (A), and drawing 24 (C) are the perspective drawing from the transverse plane. Ink cartridge 180C is formed on the circuit board 610 with same semi-conductor storage means 7 and actuator 106. As shown in drawing 24 (B) and (C), the semi-conductor storage means 7 is formed above the circuit board 610, and the actuator 106 is formed under the semi-conductor storage means 7 in the same circuit board 610. Side-attachment-wall 194b is equipped with variant O ring 614 so that the perimeter of an actuator 106 may be surrounded. Two or more formation of the caulking section 616 for joining the circuit board 610 to the ink container 194 is carried out at side-attachment-wall 194b. while the oscillating field of an actuator 106 can be made to perform contacting ink by joining the circuit board 610 to the ink container 194, and pushing variant O ring 614 against the circuit board 610 by the caulking section 616 -- the exterior and the interior of an ink cartridge -- liquid -- it is kept dense.

[0137] The terminal 612 is formed in the semi-conductor storage means 7 and semi-conductor storage means 7 neighborhood. A terminal 612 delivers the signal between the semi-conductor storage means 7 and the exteriors, such as ink jet storage. The semi-conductor storage means 7 may be constituted by the rewritable semiconductor memory of EEPROM etc. On the same circuit board 610, since it is, the semi-conductor storage means 7 and an actuator 106 end like 1 time of a shipfitter, formation, now in case an actuator 106 and the semi-conductor storage means 7 are attached in ink cartridge 180C. Moreover, the routing at the time of manufacture of ink cartridge 180C and recycle is simplified. Furthermore, since the mark of components are reduced, the manufacturing cost of ink cartridge 180C can be reduced.

[0138] An actuator 106 detects the consumption condition of the ink in the ink container 194. The semi-conductor storage means 7 stores the information on ink, such as an ink residue which the actuator 106 detected. That is, the semi-conductor storage means 7 stores the information about property parameters, such as the property of the ink used in case it detects, and an ink cartridge. The semi-conductor storage means 7 stores the resonance frequency of the time of an end, at i.e., the that the ink in the ink container 194 was consumed time, as one of the property parameters, when the ink in the ink container 194 is full beforehand (i.e., when ink is filled in the ink container 194). The ink in the ink container 194 may be stored when, as for the resonance frequency of full or an end condition, an ink jet recording device is equipped with an ink container for the first time. Moreover, as for the resonance frequency of full or an end condition, the ink in the ink container 194 may be stored during manufacture of the ink container 194. Resonance frequency in case the ink in the ink container 194 is full or an end beforehand is

stored in the semi-conductor storage means 7, and since dispersion at the time of detecting an ink residue by reading the data of resonance frequency by the ink jet recording apparatus side can be amended, it is correctly detectable that the ink residue decreased to the reference value.
[0139] Drawing 25 shows the operation gestalt of further others of an ink cartridge 180. Ink cartridge 180D shown in drawing 25 (A) equips side-attachment-wall 194b of the ink container 194 with two or more actuators 106. It is desirable to use two or more really fabricated actuators 106 which were shown in drawing 5 as an actuator 106 of these plurality. Two or more actuators 106 set spacing in the vertical direction, and are arranged at side-attachment-wall 194b. By setting two or more actuators 106 in the vertical direction, and arranging spacing for them in it at side-attachment-wall 194b, an ink residue is gradually detectable.
[0140] Ink cartridge 180E shown in drawing 25 (B) equips side-attachment-wall 194b of the ink container 194 with the actuator 606 long in the vertical direction. Change of the ink residue in the ink container 194 is continuously detectable in the vertical direction with the long actuator 606. the die length of an actuator 606 has the die length more than one half of height in side-attachment-wall 194b -- desirable -- drawing 25 (B) -- setting -- an actuator 606 -- side-attachment-wall 194b -- it has the die length to a lower limit mostly from upper limit.
[0141] Like ink cartridge 180D shown in drawing 25 (A), ink cartridge 180F shown in drawing 25 (C) equip side-attachment-wall 194b of the ink container 194 with two or more actuators 106, set predetermined spacing to confrontation of two or more actuators 106, and are equipped with the long breaking-the-water wall 192 in the vertical direction. It is desirable to use two or more really fabricated actuators 106 which were shown in drawing 5 as an actuator 106 of these plurality. The gap filled with ink is formed between an actuator 106 and the breaking-the-water wall 192. Moreover, spacing of the breaking-the-water wall 192 and an actuator 106 is vacated for extent with which ink is not held according to the capillary tube force. When the ink container 194 rolls, the wave of ink occurs in the ink container 194 interior by rolling, a gas and air bubbles will be detected by the impact with an actuator 106, and an actuator 106 may incorrect-operate by it. By establishing the breaking-the-water wall 192 like this invention, ****** of the ink of the actuator 106 neighborhood can be prevented and incorrect actuation of an actuator 106 can be prevented. Moreover, the air bubbles generated because ink rocks the breaking-the-water wall 192 prevent invading into an actuator 106.
[0142] Drawing 26 shows the operation gestalt of further others of an ink cartridge 180. Ink cartridge 180G of drawing 26 (A) have two or more septa 212 caudad prolonged from top-face 194c of the ink container 194. Since predetermined spacing is vacated, the lower limit of each septum 212 and the base of the ink container 194 are opening the pars basilaris ossis occipitalis of the ink container 194 for free passage. Ink cartridge 180G have two or more hold rooms 213 divided as two or more septa 212 be alike, respectively. The pars basilaris ossis occipitalis of two or more hold rooms 213 is mutually open for free passage. In each of two or more hold rooms 213, top-face 194c of the ink container 194 is equipped with the actuator 106. It is desirable to use the really fabricated actuator 106 which was shown in drawing 5 as an actuator 106 of these plurality. an actuator 106 -- top-face 194c of the hold room 213 of the ink container 194 -- it is mostly arranged in the center. The capacity of the hold room 213 is becoming small gradually as the capacity of the hold room 213 has the largest ink feed hopper 187 side and it keeps away from the ink feed hopper 187 into the ink container 194. Therefore, spacing by which an actuator 106 is arranged is narrow as the ink feed hopper 187 side is large and keeps away from the ink feed hopper 187 into the ink container 194.
[0143] Since ink is discharged from the ink feed hopper 187 and air enters from an air induction

inlet 185, ink is consumed at the hold room 213 of the direction in the inner part of ink cartridge 180G from the hold room 213 by the side of the ink feed hopper 187. For example, while the ink of the hold room 213 nearest to the ink feed hopper 187 was consumed and the water level of the ink of the hold room 213 nearest to the ink feed hopper 187 has fallen, ink is filled at other hold rooms 213. If all the ink of the hold room 213 nearest to the ink feed hopper 187 is consumed, air will count from the ink feed hopper 187, and will trespass upon the 2nd hold room 213, the ink in the 2nd hold room 213 will begin to be consumed, and the water level of the ink of the 2nd hold room 213 will begin to fall. It counts from the ink supply room 187, and ink is filled at this time at the hold room 213 of the 3rd henceforth. Thus, ink is consumed in order at the hold room 213 distant from the hold room 213 near the ink feed hopper 187.

[0144] Thus, since an actuator 106 sets spacing to top-face 194c of the ink container 194 and is arranged every hold room 213 at it, as for an actuator 106, reduction of the amount of ink is gradually detectable. Furthermore, since the capacity of the hold room 213 is becoming small gradually into the ink feed hopper 187 to the hold room 213, it can detect frequency highly, so that the time interval to which an actuator 106 detects reduction of the amount of ink becomes small gradually and approaches an ink end.

[0145] Ink cartridge 180H of drawing 26 (B) have one septum 212 caudad prolonged from top-face 194c of the ink container 194. Since predetermined spacing is vacated, the lower limit of a septum 212 and the base of the ink container 194 are opening the pars basilaris ossis occipitalis of the ink container 194 for free passage. Ink cartridge 180H have two hold rooms 213a and 213b divided by the septum 212. The pars basilaris ossis occipitalis of the hold rooms 213a and 213b is mutually open for free passage. The capacity of hold room 213a by the side of the ink feed hopper 187 is seen from the ink feed hopper 187, and is larger than the capacity of hold room 213b in the direction of back. As for the capacity of hold room 213b, it is desirable that it is smaller than the one half of the capacity of hold room 213a.

[0146] Top-face 194c of hold room 213b is equipped with an actuator 106. Furthermore, the buffer 214 which is the slot which catches the air bubbles into which it goes at the time of manufacture of ink cartridge 180H is formed in hold room 213b. In drawing 26 (B), a buffer 214 is formed as a slot which extends in the upper part from side-attachment-wall 194b of the ink container 194. Since the air bubbles which invaded in ink hold room 213b are caught, as for a buffer 214, an actuator 106 can prevent an ink end and the incorrect actuation to detect with air bubbles. Moreover, ink can be consumed to the last by applying the amendment corresponding to the consumption condition of the ink in hold room 213a grasped with the dot counter to the amount of ink after an ink near end is detected until it will be in ink and a condition completely by forming an actuator 106 in top-face 194c of hold room 213b. Furthermore, the amount of ink after ink near end detection which can be consumed is changeable by adjusting the capacity of hold room 213b by changing the die length and spacing of a septum 212 etc.

[0147] As for drawing 26 (C), hold room 213b of ink cartridge 180I of drawing 26 (B) is filled up with the porosity member 216. The porosity member 216 is installed so that the whole space from the top face in hold room 213b to an inferior surface of tongue may be filled. The porosity member 216 contacts an actuator 106. During the reciprocating motion the time of an ink container falling, and on carriage, air may invade in ink hold room 213b, and this may cause incorrect actuation of an actuator 106. However, if it has the porosity member 216, it can prevent catching air and air going into an actuator 106. Moreover, since the porosity member 216 holds ink, when an ink container shakes, it can prevent applying ink to an actuator 106 and an actuator 106 incorrect-detecting those without ink with those with ink. As for the porosity member 216, it

is desirable to install in the hold room 213 where capacity is the smallest. Moreover, by forming an actuator 106 in top-face 194c of nature of hold 213b, amendment can be applied to the amount of ink after an ink near end is detected until it will be in ink and a condition completely, and ink can be consumed to the last. Furthermore, the amount of ink after ink near end detection which can be consumed is changeable by adjusting the capacity of hold room 213b by changing the die length and spacing of a septum 212 etc.

[0148] Drawing 26 (D) shows ink cartridge 180J from which the porosity member 216 of ink cartridge 180I of drawing 26 (C) is constituted by two kinds of porosity members 216A and 216B from which an aperture differs. Porosity member 216A is arranged above porosity member 216B. The aperture of upper porosity member 216A is larger than the aperture of lower porosity member 216B. Or porosity member 216A is formed by the member with low liquid compatibility rather than porosity member 216B. Since the capillary tube force is larger than large porosity member 216A of an aperture, the ink in hold room 213b gathers for lower porous chamber portion material 216B, and the direction of small porosity member 216B of an aperture is held. Therefore, once even an actuator 106 reaches and air detects those without ink, ink will reach an actuator again and it will not detect with those with ink. Furthermore, ****** of about 106-actuator ink becomes good by ink being absorbed by porosity member 216B of a side far from an actuator 106, and the variation of the acoustic-impedance change when detecting ink existence becomes large. Moreover, by forming an actuator 106 in top-face 194c of nature of hold 213b, amendment can be applied to the amount of ink after an ink near end is detected until it will be in ink and a condition completely, and ink can be consumed to the last. Furthermore, the amount of ink after ink near end detection which can be consumed is changeable by adjusting the capacity of hold room 213b by changing the die length and spacing of a septum 212 etc.

[0149] Drawing 27 is the sectional view showing ink cartridge 180K which are other operation gestalten of ink cartridge 180I shown in drawing 26 (C). The porosity member 216 of an ink cartridge 180 shown in drawing 27 is compressed so that the horizontal cross section of the lower part of the porosity member 216 becomes small gradually towards the direction of the base of the ink container 194, and it is designed so that an aperture may become small. In order to compress ink cartridge 180K of drawing 27 (A) so that the aperture in the direction of under the porosity member 216 becomes small, the rib is prepared in the side attachment wall. Since the aperture of the porosity member 216 lower part is small by being compressed, ink is collected in the porosity member 216 lower part, and is held. By ink being absorbed by the porosity member 216 lower part of a side far from an actuator 106, ****** of about 106-actuator ink becomes good, and the variation of the acoustic-impedance change when detecting ink existence becomes large. Therefore, when ink shakes, ink is applied to the actuator 106 with which ink cartridge 180K top face was equipped, it can keep, and an actuator 106 can prevent incorrect-detecting those without ink with those with ink.

[0150] On the other hand, in order that the horizontal cross section of the lower part of the porosity member 216 may compress ink cartridge 180L of drawing 27 (B) and drawing 27 (C) in the cross direction of the ink container 194 to become small gradually towards the base of the ink container 194, the horizontal cross section of a hold room is becoming small gradually towards the direction of the base of the ink container 194. Since the aperture of the porosity member 216 lower part is small by being compressed, ink is collected in the lower part of the porosity member 216, and is held. By ink being absorbed by the lower part of porosity member 216B of a side far from an actuator 106, ****** of about 106-actuator ink becomes good, and the variation of the acoustic-impedance change when detecting ink existence becomes large. Therefore, when

ink shakes, ink is applied to the actuator 106 with which the top face of ink cartridge 180L was equipped, it can keep, and an actuator 106 can prevent incorrect-detecting those without ink with those with ink.

[0151] Drawing 28 shows the operation gestalt of further others of the ink cartridge which used the actuator 106. Ink cartridge 220A of drawing 28 (A) has the 1st septum 222 formed so that it might extend from the top face of ink cartridge 220A to a lower part. Since predetermined spacing is vacated between the lower limit of the 1st septum 222, and the base of ink cartridge 220A, ink can flow into the ink feed hopper 230 through the base of ink cartridge 220A. From the 1st septum 222, the 2nd septum 224 is formed in the ink feed hopper 230 side so that it may extend more nearly up than the base of ink cartridge 220A. Since predetermined spacing is vacated between the upper limit of the 2nd septum 224, and an ink cartridge 220A top face, ink can flow into the ink feed hopper 230 through the top face of ink cartridge 220A.

[0152] By the 1st septum 222, it sees from the ink feed hopper 230, and 1st hold room 225a is formed in the direction in the inner part of the 1st septum 222. On the other hand, by the 2nd septum 224, it sees from the ink feed hopper 230, and 2nd hold room 225b is formed in the near side of the 2nd septum 224. The capacity of 1st hold room 225a is larger than the capacity of 2nd hold room 225b. The capillary tube way 227 is formed by vacating only spacing which can cause capillarity between the 1st septum 222 and the 2nd septum 224. Therefore, the ink of 1st hold room 225a is brought together in the capillary tube way 227 according to the capillary tube force of the capillary tube way 227. Therefore, a gas and air bubbles can prevent mixing to 2nd hold room 225b. Moreover, the water level of the ink in 2nd hold room 225b can descend gradually stably. Since it sees from the ink feed hopper 230 and 1st hold room 225a is formed in the back from 2nd hold room 225b, after the ink of 1st hold room 225a is consumed, the ink of 2nd hold room 225b is consumed.

[0153] The side attachment wall by the side of the ink feed hopper 230 of ink cartridge 220A, i.e., the side attachment wall by the side of the ink feed hopper 230 of 2nd hold room 225b, is equipped with the actuator 106. An actuator 106 detects the consumption condition of the ink in 2nd hold room 225b. By equipping the side attachment wall of 2nd hold room 225b with an actuator 106, when near, an ink residue is stably detectable with an ink end. Furthermore, it can set up freely which time the ink residue in is made into an ink end by changing the height which equips the side attachment wall of 2nd hold room 225b with an actuator 106. Since an actuator 106 is not influenced by the ink by rolling of ink cartridge 220A of rolling when ink is supplied to 2nd hold room 225b by the capillary tube way 227 from 1st hold room 225a, an actuator 106 can measure an ink residue certainly. Furthermore, since the capillary tube way 227 holds ink, ink protects flowing backwards to 1st hold room 225a from 2nd hold room 225b.

[0154] The check valve 228 is formed in the top face of ink cartridge 220A. By the check valve 228, when ink cartridge 220A rolls, it can prevent ink leaking to the ink cartridge 220A exterior. Furthermore, the evaporation from ink cartridge 220A of ink can be prevented by installing a check valve 228 in the top face of ink cartridge 220A. If the ink in ink cartridge 220A is consumed and the negative pressure in ink cartridge 220A exceeds the pressure of a check valve 228, a check valve 228 will open, air will be inhaled to ink cartridge 220A, it will close after that, and the pressure in ink cartridge 220A will be held uniformly.

[0155] Drawing 28 (C) and (D) show the cross section of the detail of a check valve 228. The check valve 228 of drawing 28 (C) has the valve 232 which has wing 232a formed of rubber. The air hole 233 with the exterior of an ink cartridge 220 counters wing 232a, and is prepared in an ink cartridge 220. An air hole 233 is opened and closed by wing 232a. If the ink in an ink

cartridge 220 decreases in number and, as for a check valve 228, the negative pressure in an ink cartridge 220 exceeds the pressure of a check valve 228, wing 232a will open inside an ink cartridge 220, and will adopt external air in an ink cartridge 220. The check valve 228 of drawing 28 (D) has the valve 232 and spring 235 which were formed of rubber. If the negative pressure in an ink cartridge 220 exceeds the pressure of a check valve 228, a valve 232 will press and open a spring 235, will inhale external air in an ink cartridge 220, will close a check valve 228 after that, and it will hold the negative pressure in an ink cartridge 220 uniformly.
[0156] Ink cartridge 220B of drawing 28 (B) arranges the porosity member 242 to 1st hold room 225a instead of forming a check valve 228 in ink cartridge 220A of drawing 28 (A). The porosity member 242 prevents ink leaking to the exterior of ink cartridge 220B, when ink cartridge 220B rolls, while holding the ink in ink cartridge 220B.
[0157] As mentioned above, in the carriage and the ink cartridge of another object with which carriage is equipped, although the case where an ink cartridge or carriage was equipped with an actuator 106 was described, it unites with carriage and the ink tank with which an ink jet recording apparatus is equipped with carriage may be equipped with an actuator 106. Furthermore, the ink tank of the off-carriage method which supplies ink to carriage may be equipped with an actuator 106 through the tube of carriage and another object etc. Furthermore, the ink cartridge which the recording head and the ink container were united and was constituted exchangeable may be equipped with the actuator of this invention.
[0158] As mentioned above, although this invention was explained using the gestalt of operation, the technical range of this invention is not limited to the range given in the gestalt of the above-mentioned implementation. Various modification or amelioration can be added to the gestalt of the above-mentioned implementation. It is clear from the publication of a claim that the gestalt's which added such modification or amelioration it may be contained in the technical range of this invention.
[0159]
[Effect of the Invention] The piezoelectric device of this invention, a module object, and a liquid container can detect the residue of a liquid correctly, and its complicated seal structure is unnecessary.

## TECHNICAL FIELD

[Field of the Invention] This invention is detecting change of an acoustic impedance, and relates to the liquid container with which it had the piezoelectric device (actuator) for detecting the consumption condition of the liquid in the liquid container which holds liquids, such as ink, by detecting change of resonance frequency also especially in it. In more detail, the ink of a pressure generating room is made equivalent to print data with a pressure generating means, and it pressurizes, and is related with the piezoelectric device suitable for the ink jet recording apparatus which is made to breathe out an ink droplet and is printed from a nozzle orifice, a module object, and a liquid container.

## PRIOR ART

[Description of the Prior Art] An ink jet recording device carries the ink jet recording head equipped with a pressure generating means to pressurize a pressure generating room, and the nozzle orifice which carries out the regurgitation of the pressurized ink as an ink droplet from a nozzle orifice in carriage. The ink jet recording device is constituted possible [ continuation of printing ], supplying the ink of an ink tank to a recording head through passage. When ink is consumed, the ink tank is constituted as a removable cartridge so that a user can exchange easily. [0003] Conventionally, there is a method of managing the time of specified quantity consumption of the ink actually being carried out etc. the approach of software integrating the amount of ink attracted by the number of regurgitation of the ink droplet in a recording head, or maintenance as a management method of ink consumption of an ink cartridge, and managing ink consumption by count, and by attaching the electrode for oil-level detection in an ink cartridge. [0004] However, the approach of software integrating the number of regurgitation and the amount of ink of an ink droplet, and managing ink consumption on count has the problem that an error arises according to the printing gestalt in a user side etc., and gross errors arise at the time of re-wearing of the same cartridge. Moreover, there was also a problem that the error which the pressure in an ink cartridge and the viscosity of ink change with the elapsed time after opening of height with a going too far room temperature or an ink cartridge etc., and cannot be disregarded between the ink consumption on count and actual consumption will arise by the operating environment. Since the method of on the other hand managing the time of ink being consumed with an electrode can detect the amount of real of ink, it can manage an ink residue with high dependability. However, since it depends for detection of the oil level of ink on the conductivity of ink, the class of detectable ink is limited and there is a problem which the seal structure of an electrode complicates. Moreover, since noble metals good [ usually ] conductivity and high were used as an ingredient of an electrode, there were corrosion resistance and a problem that the manufacturing cost of an ink cartridge increased. Furthermore, since it was necessary to equip with two electrodes, the production process increased and there was also a problem that a manufacturing cost will increase as a result.

## EFFECT OF THE INVENTION

[Effect of the Invention] The piezoelectric device of this invention, a module object, and a liquid container can detect the residue of a liquid correctly, and its complicated seal structure is unnecessary.

## TECHNICAL PROBLEM

[Problem(s) to be Solved by the Invention] This invention relates to the liquid container with which it had the piezoelectric device for detecting the consumption condition of the liquid in the liquid container which holds a liquid by detecting change of an impedance from resonance frequency. In more detail, make the ink of a pressure generating room equivalent to print data with a pressure generating means, pressurize, and it prepares for the ink cartridge applied to the

ink jet recording apparatus which is made to breathe out an ink droplet and is printed from a nozzle orifice. It is related with the piezoelectric device and module object which detect the consumption condition of the ink in an ink cartridge.

## MEANS

[Means for Solving the Problem] Namely, the piezoelectric device in the 1st gestalt of this invention The oscillating section which is the piezoelectric device with which a liquid container is equipped, and which detects the consumption condition of the liquid in this liquid container, and vibrates in a piezoelectric device The lower electrode with which one field was formed in the field of another side of the diaphragm in contact with the liquid in a liquid container, and this diaphragm, It has the up electrode formed the piezo-electric layer formed on this lower electrode, and on this piezo-electric layer, and it is desirable that the up electrode covered the lower electrode and the piezo-electric layer has overflowed rather than the up electrode while the oscillating section is formed so that a piezo-electric layer may cover a lower electrode.
[0007] Moreover, as for a piezoelectric device, it is desirable to have the cavity where a top face touches the inferior-surface-of-tongue side in contact with the liquid of a diaphragm, and an inferior surface of tongue is further equipped with the substrate in contact with the liquid in a liquid container and where a substrate contacts a liquid in the location of the vibrating part of a diaphragm. Furthermore, it is desirable that the area of a cavity is larger than the area of a lower electrode. As for deformation of the diaphragm by residual vibration, it is desirable that it is larger than deformation of a substrate. The area of the part which generates the piezo-electric effect of a piezo-electric layer may be almost the same as the area of a lower electrode. Moreover, it is desirable that the principal part of an up electrode, a piezo-electric layer, and a lower electrode is a rectangle. The principal part of an up electrode, a piezo-electric layer, and a lower electrode may be almost circular. A cavity is almost circular and it is desirable that the value which broke the radius of a cavity by the depth of a cavity is larger than 3pi/8. It is desirable that a piezoelectric device detects the consumption condition of the liquid in a liquid container by detecting change of the acoustic impedance near the oscillating section. Moreover, it is desirable that a piezoelectric device detects change of an acoustic impedance and detects the consumption condition of the liquid in a liquid container by generating back EMF by the residual vibration produced by the oscillation of a piezo-electric layer. Moreover, it is desirable that it is the liquid container with which it is equipped with the above-mentioned piezoelectric device. Furthermore, as for a piezoelectric device, it is desirable to be prepared in the through-hole formed in the wall surface of a liquid container or a crevice.
[0008] The module object in the 2nd gestalt of this invention It is a module object for a liquid container being equipped and detecting the consumption condition of the liquid in a liquid container. A module object The piezoelectric device which detects the consumption condition of a liquid by generating back EMF by the residual vibration which remains after an oscillation, It has the attachment structure united with the piezoelectric device for attaching a piezoelectric device in a liquid container. A piezoelectric device The lower electrode with which one field was formed in the field of another side of the diaphragm in contact with the liquid in a liquid container, and this diaphragm, It has the up electrode prepared on the piezo-electric layer formed on this lower electrode, and this piezo-electric layer, while a piezo-electric layer is formed so that a lower electrode may be covered, an up electrode covers a lower electrode, and as for a

piezo-electric layer, having overflowed rather than the up electrode is desirable.
[0009] Furthermore, as for the attachment structure, it is desirable that a top face faces the inferior-surface-of-tongue side in contact with the liquid of a diaphragm, have the attachment member to which an inferior surface of tongue contacts the liquid in a liquid container, and an attachment member has the cavity which contacts a liquid in the location of the vibrating part of a diaphragm. Furthermore, as for the area of a cavity, it is desirable that it is larger than the area of a lower electrode. A cavity is almost circular and it is desirable that the value which broke the radius of a cavity by the depth of a cavity is larger than 3pi/8. A piezoelectric device may be arranged in a core for the attachment structure of a module object by opening including opening. Furthermore, as for the area of opening, it is desirable that it is larger than the area of the part which generates the piezo-electric effect of a piezo-electric layer. Moreover, a piezoelectric device may be removable to the attachment structure. Furthermore, it is desirable that it is the liquid container with which the above-mentioned module object has been arranged.
[0010] In addition, the outline of the above-mentioned invention is not what enumerated all the required descriptions of this invention, and the subcombination of these characterizing group can also be invented.
[0011]
[Embodiment of the Invention] Although this invention is hereafter explained through the gestalt of implementation of invention, not all the combination of the description of the following operation gestalten that do not limit invention concerning a claim and are explained in the operation gestalt is necessarily indispensable for the solution means of invention.
[0012] The underlying concept of this invention is using an oscillating phenomenon, and is detecting the condition (the existence of the liquid in a liquid container, the amount of a liquid, the water level of a liquid, the class of liquid, and the presentation of a liquid being included) of the liquid in a liquid container. Some approaches can be considered as detection of the condition of the liquid in the liquid container using a concrete oscillating phenomenon. For example, an elastic wave generating means generates an elastic wave to the interior of a liquid container, and there is a method of detecting the medium in a liquid container and change of the condition by receiving the reflected wave reflected with an oil level or the wall which counters. Moreover, there is also the approach of detecting change of an acoustic impedance apart from this from the oscillation characteristic of the vibrating body. As an approach of using change of an acoustic impedance By vibrating the oscillating section of the piezoelectric device or actuator which has a piezoelectric device, and measuring back EMF produced by the residual vibration which remains in the oscillating section after that The approach of detecting change of an acoustic impedance by detecting resonance frequency or the back EMF wave amplitude, The impedance characteristic or admittance property of a liquid is measured with impedance analyzers, such as a measurement machine, for example, a propagation circuit etc., and there is the approach of measuring change by the frequency of the current value when giving a current value, an electrical-potential-difference value change, or vibration to a liquid or an electrical-potential-difference value. Hereafter, the detail of the principle of operation of a piezoelectric device or an actuator is explained.
[0013] Drawing 1 and drawing 2 show the detail and equal circuit of an actuator 106 which are 1 operation gestalt of a piezoelectric device. An actuator here is used for the approach of detecting change of an acoustic impedance at least and detecting the consumption condition of the liquid in a liquid container. It is used for the approach of detecting change of an acoustic impedance at least and detecting the consumption condition of the liquid in a liquid container because

resonance frequency detects by residual vibration especially. Drawing 1 (A) is the expansion top view of an actuator 106. Drawing 1 (B) shows the B-B cross section of an actuator 106. Drawing 1 (C) shows the C-C cross section of an actuator 106. Furthermore, drawing 2 (A) and drawing 2 (B) show the equal circuit of an actuator 106. Moreover, drawing 2 (C) and drawing 2 (D) show the circumference containing the actuator 106 when ink is filled in the ink cartridge, respectively, and its equal circuit, and drawing 2 (E) and drawing 2 (F) show the circumference containing the actuator 106 in case there is no ink into an ink cartridge, respectively, and its equal circuit.

[0014] The substrate 178 with which an actuator 106 has the opening 161 of a circle configuration in the center mostly, The diaphragm 176 arranged in one field (henceforth a front face) of a substrate 178 so that opening 161 may be covered, The piezo-electric layer 160 arranged at the front-face side of a diaphragm 176, and the up electrode 164 and the lower electrode 166 which inserts the piezo-electric layer 160 from both, It has the auxiliary electrode 172 which is arranged between the up electrode terminal 168 electrically combined with the up electrode 164, the lower electrode terminal 170 electrically combined with the lower electrode 166, and the up electrode 164 and the up electrode terminal 168, and combines both electrically. The piezo-electric layer 160, the up electrode 164, and the lower electrode 166 have a circular part as each principal part. Each circular part of the piezo-electric layer 160, the up electrode 164, and the lower electrode 166 forms a piezoelectric device.

[0015] A diaphragm 176 is formed in the front face of a substrate 178 so that opening 161 may be covered. A cavity 162 is formed of the opening 161 of a diaphragm 176, the facing part, and the opening 161 of the front face of a substrate 178. With the piezoelectric device of a substrate 178, the field (henceforth a rear face) of the opposite side faces the liquid-container side, and the cavity 162 is constituted so that a liquid may be contacted. even if a liquid enters in a cavity 162, a liquid does not leak to the front-face side of a substrate 178 -- as -- a diaphragm 176 -- a substrate 178 -- receiving -- liquid -- it is attached densely.

[0016] The front face of a diaphragm 176, i.e., a liquid container, is located in the field of the opposite side, and the lower electrode 166 is attached so that the core of a circular part and the core of opening 161 which are the principal part of the lower electrode 166 may be mostly in agreement. In addition, it is set up so that the area of the circular part of the lower electrode 166 may become smaller than the area of opening 161. On the other hand, the piezo-electric layer 160 is formed in the front-face side of the lower electrode 166 so that the core of the circular part and the core of opening 161 may be mostly in agreement. The area of the circular part of the piezo-electric layer 160 is set up so that it may become larger than the area of the circular part of the lower electrode 166 smaller than the area of opening 161.

[0017] On the other hand, it is formed in the front-face side of the piezo-electric layer 160 so that the core of a circular part and the core of opening 161 that the up electrode 164 is the principal part may be mostly in agreement. The area of the circular part of the up electrode 164 is set up so that it may become larger than the area of the circular part of the lower electrode 166 smaller than the area of the circular parts of opening 161 and the piezo-electric layer 160.

[0018] Therefore, the principal part of the piezo-electric layer 160 has structure inserted and crowded from a front-face and rear-face side, respectively by the principal part of the up electrode 164, and the principal part of the lower electrode 166, and can carry out the deformation drive of the piezo-electric layer 160 effectively. The circular part which is each principal part of the piezo-electric layer 160, the up electrode 164, and the lower electrode 166 forms the piezoelectric device in an actuator 106. The piezoelectric device is in contact with the diaphragm 176 as mentioned above. Moreover, opening 161 has the largest area among the

circular parts of the circular parts of the circular part of the up electrode 164, and the piezo-electric layer 160, and the lower electrode 166, and opening 161. The oscillating field which actually vibrates among diaphragms 176 according to this structure is determined by opening 161. Moreover, since the circular parts of the circular part of the up electrode 164 and the piezo-electric layer 160 and the circular part of the lower electrode 166 have an area smaller than opening 161, a diaphragm 176 becomes easier to vibrate. Furthermore, the circular part of the lower electrode 166 is smaller among the circular part of the lower electrode 166 electrically connected with the piezo-electric layer 160, and the circular part of the up electrode 164. Therefore, the circular part of the lower terminal 166 determines the part which generates the piezo-electric effect among the piezo-electric layers 160.

[0019] Therefore, the principal part of the piezo-electric layer 160 has structure inserted and crowded from a front-face and rear-face side, respectively by the principal part of the up electrode 164, and the principal part of the lower electrode 166, and can carry out the deformation drive of the piezo-electric layer 160 effectively. The circular part which is each principal part of the piezo-electric layer 160, the up electrode 164, and the lower electrode 166 forms the piezoelectric device in an actuator 106. The piezoelectric device is in contact with the diaphragm 176 as mentioned above. Moreover, opening 161 has the largest area among the circular parts of the circular parts of the circular part of the up electrode 164, and the piezo-electric layer 160, and the lower electrode 166, and opening 161. The oscillating field which actually vibrates among diaphragms 176 according to this structure is determined by opening 161. Moreover, since the circular parts of the circular part of the up electrode 164 and the piezo-electric layer 160 and the circular part of the lower electrode 166 have an area smaller than opening 161, a diaphragm 176 becomes easier to vibrate. Furthermore, the circular part of the lower electrode 166 is smaller among the circular part of the lower electrode 166 electrically connected with the piezo-electric layer 160, and the circular part of the up electrode 164. Therefore, the circular part of the lower terminal 166 determines the part which generates the piezo-electric effect among the piezo-electric layers 160.

[0020] The core of the circular parts of the piezo-electric layer 160 which forms a piezoelectric device, the up electrode 164, and the lower electrode 166 corresponds with the core of opening 161 mostly. moreover, the core of the opening 161 of a circle configuration of determining the vibrating part of a diaphragm 176 -- an actuator 106 -- it is mostly prepared in the core. Therefore, the core of the oscillating section of an actuator 106 is mostly in agreement with the core of an actuator. Furthermore, since the principal piece of a piezoelectric device and the vibrating part of a diaphragm 176 have a circular configuration, the oscillating section of an actuator 106 is a symmetrical configuration to the core of an actuator 106.

[0021] Since the oscillating section is a symmetrical configuration, it can be prevented from exciting an unnecessary vibration produced from the asymmetry of structure to the core of an actuator 106. Therefore, the detection precision of resonance frequency improves. Furthermore, to an actuator core, since the oscillating section is a symmetrical configuration, it is easy to manufacture it and it can make small dispersion in the configuration for every piezoelectric device. Therefore, dispersion in the resonance frequency for every piezoelectric device becomes small. Moreover, since the oscillating section is an isotropic configuration, it is hard to be influenced of dispersion in immobilization in the case of adhesion. A liquid container is pasted equally. Therefore, the mounting nature to the liquid container of an actuator 106 is good.

[0022] Furthermore, since the vibrating part of a diaphragm 176 has a circular configuration, in the resonance mode of the residual vibration of the piezo-electric layer 160, the resonance mode

of a low degree, for example, primary, becomes dominant, and a single peak appears. Therefore, since a peak and a noise are clearly distinguishable, resonance frequency is clearly detectable. Moreover, by enlarging area of the vibrating part of the diaphragm 176 of a circular configuration, the difference of the back EMF wave amplitude and the amplitude of the resonance frequency by the existence of a liquid becomes large, and can improve the precision of detection of resonance frequency further.

[0023] The variation rate by vibration of a diaphragm 176 is farther [ than the variation rate by vibration of a substrate 178 ] large. Compliance is small, namely, an actuator 106 has the two-layer structure of the substrate 178 which is hard to displace by vibration, and the diaphragm 176 which compliance is large, namely, is easy to displace by vibration. According to this two-layer structure, since the variation rate of the diaphragm 176 by vibration can be enlarged certainly being fixed to a liquid container by the substrate 178, the difference of the back EMF wave amplitude and the amplitude of the resonance frequency by the existence of a liquid becomes large, and the precision of detection of resonance frequency can be improved. Furthermore, since the compliance of a diaphragm 176 is large, attenuation of vibration becomes small and the precision of detection of resonance frequency can be improved. Moreover, the knot of vibration of an actuator 106 is located near the edge of the periphery section 161 of a cavity 162, i.e., opening.

[0024] The up electrode terminal 168 is formed in the front-face side of a diaphragm 176 so that it may connect with the up electrode 164 electrically through an auxiliary electrode 172. On the other hand, the lower electrode terminal 170 is formed in the front-face side of a diaphragm 176 so that it may connect with the lower electrode 166 electrically. Since the up electrode 164 is formed in the front-face side of the piezo-electric layer 160, it needs to have a level difference equal to the sum of the thickness of the piezo-electric layer 160, and the thickness of the lower electrode 166 while connecting with the up electrode terminal 168. The connection condition of the up electrode 164 and the up electrode terminal 168 becomes weak, and forming this level difference only with the up electrode 164 has risk of cutting, even if it is difficult and possible in a loan. Then, the up electrode 164 and the up electrode terminal 168 are connected, using an auxiliary electrode 172 as an auxiliary member. It becomes possible for the piezo-electric layer 160 and the up electrode 164 to serve as structure supported by the auxiliary electrode 172, and to be able to obtain a desired mechanical strength, and to ensure connection between the up electrode 164 and the up electrode terminal 168 by doing in this way.

[0025] In addition, the oscillating field which faces a piezoelectric device and the piezoelectric device of the diaphragms 176 is the oscillating section which actually vibrates in an actuator 106. Moreover, as for the member contained in an actuator 106, being formed in one is desirable by being calcinated mutually. By forming an actuator 106 in one, the handling of an actuator 106 becomes easy. Furthermore, an oscillation characteristic improves by raising the reinforcement of a substrate 178. That is, by raising the reinforcement of a substrate 178, only the oscillating section of an actuator 106 vibrates and any parts other than the oscillating section do not vibrate among actuators 106. Moreover, in order for any parts other than the oscillating section of an actuator 106 not to vibrate, it can attain by making the piezoelectric device of an actuator 106 thinly and small, and making a diaphragm 176 thin to raising the reinforcement of a substrate 178.

[0026] It is desirable to use the lead loess piezoelectric film which does not use PZT (PZT), the PZT lanthanum (PLZT), or lead as an ingredient of the piezo-electric layer 160, and it is desirable to use a zirconia or an alumina as an ingredient of a substrate 178. Moreover, it is

desirable to use the same ingredient as a substrate 178 for a diaphragm 176. Metals, such as the ingredient which has conductivity, for example, gold, silver, copper, platinum, aluminum, and nickel, can be used for the up electrode 164, the lower electrode 166, the up electrode terminal 168, and the lower electrode terminal 170.

[0027] The actuator 106 constituted as mentioned above is applicable to the container which holds a liquid. For example, the container which held the penetrant remover for washing the ink cartridge and ink tank which are used for an ink jet recording apparatus, or a recording head can be equipped.

[0028] The predetermined location of a liquid container is equipped with the actuator 106 shown in drawing 1 and drawing 2 so that the liquid held in a liquid container in a cavity 162 may be contacted. When the liquid is fully held in the liquid container, the inside of a cavity 162 and its outside are filled by the liquid. On the other hand, if the liquid of a liquid container is consumed and an oil level descends below to the stowed position of an actuator, a liquid does not exist in a cavity 162, or a liquid remains only in a cavity 162, and it will be in the condition that a gas exists on the outside. An actuator 106 detects the difference of an acoustic impedance as it is [ originating in change of this condition, and ] few. By it, an actuator 106 can detect whether it is in the condition that the liquid is fully held in the liquid container, or it is in the condition that a certain liquid more than fixed was consumed. Furthermore, an actuator 106 can also detect the class of liquid in a liquid container.

[0029] Here explains the principle of the oil-level detection by the actuator.

[0030] In order to detect change of the acoustic impedance of a medium, the impedance characteristic or admittance property of a medium is measured. A propagation circuit can be used when measuring an impedance characteristic or an admittance property. A propagation circuit impresses a fixed electrical potential difference to a medium, and measures the current which changes a frequency and flows to a medium. Or a propagation circuit supplies a fixed current to a medium, and measures the electrical potential difference which changes a frequency and is impressed to a medium. The current value or electrical-potential-difference value change measured by the propagation circuit shows change of an acoustic impedance. Moreover, change of the frequency fm from which a current value or an electrical-potential-difference value serves as the maximum or the minimum also shows change of an acoustic impedance.

[0031] Apart from the above-mentioned approach, an actuator can detect change of the acoustic impedance of a liquid using change of only resonance frequency. A piezoelectric device can be used, when using the approach of detecting resonance frequency by measuring back EMF produced by the residual vibration which remains in the oscillating section, as an approach of using change of the acoustic impedance of a liquid after the oscillating section of an actuator vibrates. A piezoelectric device is a component which generates back EMF by the residual vibration which remains in the oscillating section of an actuator, and the magnitude of back EMF changes with the amplitude of the oscillating section of an actuator. Therefore, it is easy to carry out detection, so that the amplitude of the oscillating section of an actuator is large. Moreover, the period from which the magnitude of back EMF changes with the frequencies of the residual vibration in the oscillating section of an actuator changes. Therefore, the frequency of the oscillating section of an actuator is equivalent to the frequency of back EMF. Here, resonance frequency says the frequency in the resonance state with the medium which touches the oscillating section and the oscillating section of an actuator.

[0032] In order to obtain resonance frequency fs, the Fourier transform of the wave acquired by the back EMF measurement in case the oscillating section and a medium are the resonance state

is carried out. Since vibration of an actuator is accompanied not by deformation of only an one direction but by various deformation, such as a deflection and expanding, it has various frequencies including resonance frequency fs. Therefore, the Fourier transform of the wave of back EMF in case a piezoelectric device and a medium are the resonance state is carried out, and resonance frequency fs is judged by specifying the most dominant frequency component.
[0033] The admittance of a medium of a frequency fm is a frequency in case the maximum or an impedance is the minimum. If it is resonance frequency fs, a frequency fm will produce few errors to resonance frequency fs by dielectric loss or a mechanical loss of a medium etc. However, since time and effort is taken, generally deriving resonance frequency fs from the frequency fm surveyed replaces with and uses a frequency fm for resonance frequency. Here, an actuator 106 can detect an acoustic impedance at least in inputting the output of an actuator 106 into a propagation circuit.
[0034] It is proved to be the approach of measuring resonance frequency fs by experiment by measuring the approach of measuring the impedance characteristic or admittance property of a medium, and measuring a frequency fm, and back EMF produced by residual vibration vibration in the oscillating section of an actuator that there is almost no difference in the resonance frequency specified as be alike.
[0035] The oscillating field of an actuator 106 is a part which constitutes the cavity 162 determined by opening 161 among diaphragms 176. When the liquid is fully held in the liquid container, in a cavity 162, a liquid is filled and an oscillating field contacts the liquid in a liquid container. On the other hand, when there is no enough liquid into a liquid container, an oscillating field does not contact a liquid in contact with the liquid which remained in the cavity in a liquid container, but contacts a gas or a vacuum.
[0036] A cavity 162 is formed in the actuator 106 of this invention, and it can design so that the liquid in a liquid container may remain in the oscillating field of an actuator 106 by it. The reason is as follows.
[0037] Although there is an oil level of the liquid in a liquid container caudad depending on [ stowed position / of an actuator ] whenever [ installation location / to the liquid container of an actuator /, or setting-angle ], a liquid may adhere to the oscillating field of an actuator. When the actuator has detected the existence of a liquid only by the existence of the liquid in an oscillating field, the liquid adhering to the oscillating field of an actuator bars exact detection of the existence of a liquid. for example, the time of the condition that there is an oil level caudad rather than the stowed position of an actuator -- both-way migration of carriage etc. -- a liquid container -- rocking -- a liquid -- a wave -- inside, if a drop adheres to an oscillating field, an actuator will make a judgment which if liquids of enough are in a liquid container mistook. Then, malfunction of an actuator can be prevented, even if it is the case where a liquid is remained conversely there and an oil level is [ a liquid container rocks and ] choppy by preparing positively the cavity designed so that the existence of a liquid might be detected correctly. Thus, malfunction can be prevented by using the actuator which has a cavity.
[0038] Moreover, as shown in drawing 2 (E), there is no liquid into a liquid container and let the case where the liquid in a liquid container remains in the cavity 162 of an actuator 106 be the threshold of the existence of a liquid. That is, there is no liquid around a cavity 162 and it judges that he has no ink when there are few liquids in a cavity than this threshold, a liquid is around a cavity 162, and when there are more liquids than this threshold, it is judged as those with ink. For example, when the side attachment wall of a liquid container is equipped with an actuator 106, the case where the liquid in a liquid container is below the stowed position of an actuator is

judged to have no ink, and the case where the liquid in a liquid container is above the stowed position of an actuator is judged to be those with ink. Thus, even if it is a time of the ink in a cavity drying and ink being lost by setting up a threshold, it judges that he has no ink, and since a threshold is not exceeded even if ink adheres to a cavity again in the shake of carriage etc. at the place whose ink in a cavity was lost, it can be judged that he has no ink.
[0039] Here, the actuation and the principle which detect the condition of the liquid in a liquid container from the resonance frequency of the medium and the oscillating section of an actuator 106 by measurement of back EMF are explained, referring to drawing 1 and drawing 2 . In an actuator 106, an electrical potential difference is impressed to the up electrode 164 and the lower electrode 166 through the up electrode terminal 168 and the lower electrode terminal 170, respectively. Electric field arise into the part pinched by the up electrode 164 and the lower electrode 166 among the piezo-electric layers 160. The piezo-electric layer 160 deforms by the electric field. When the piezo-electric layer 160 deforms, the oscillating field of the diaphragms 176 oscillates flexurally. After the piezo-electric layer 160 deforms, flexural oscillation remains in the oscillating section of an actuator 106 for the time being.
[0040] Residual vibration is the free vibration of the oscillating section of an actuator 106, and a medium. Therefore, by making into pulse shape or a square wave the electrical potential difference impressed to the piezo-electric layer 160, after impressing an electrical potential difference, the resonance state of the oscillating section and a medium can be acquired easily. Residual vibration also deforms the piezo-electric layer 160 in order to vibrate the oscillating section of an actuator 106. Therefore, the piezo-electric layer 160 generates back EMF. The back EMF is detected through the up electrode 164, the lower electrode 166, the up electrode terminal 168, and the lower electrode terminal 170. Since resonance frequency can be specified, the condition of the liquid in a liquid container is detectable with detected back EMF.
[0041] Generally, it is resonance frequency fs. fs=1/(2*pi*(M*Cact) 1/2) (formula 1)
It is come out and expressed. Here, M is the sum of the inertance Mact of the oscillating section, and addition inertance M'. Cact is the compliance of the oscillating section.
[0042] Drawing 1 (C) is the sectional view of the actuator 106 when ink does not remain in a cavity in this example. Drawing 2 (A) and drawing 2 (B) are the oscillating section of the actuator 106 when ink does not remain in a cavity, and the equal circuit of a cavity 162.
[0043] Mact should ** the product of the thickness of the oscillating section, and the consistency of the oscillating section in the area of the oscillating section, and should show it further to a detail at drawing 2 (A). Mact=Mpzt+Melectrode1+Melectrode2+Mvib (formula 2)
It is expressed. Here, Mpzt ** the product of the thickness of the piezo-electric layer 160 and the consistency of the piezo-electric layer 160 in the oscillating section in the area of the piezo-electric layer 160. Melectrode1 ** the product of the thickness of the up electrode 164 and the consistency of the up electrode 164 in the oscillating section in the area of the up electrode 164. Melectrode2 ** the product of the thickness of the lower electrode 166 and the consistency of the lower electrode 166 in the oscillating section in the area of the lower electrode 166. Mvib ** the product of the thickness of a diaphragm 176 and the consistency of a diaphragm 176 in the oscillating section in the area of the oscillating field of a diaphragm 176. However, in this example, although each area of the oscillating field of the piezo-electric layer 160, the up electrode 164, the lower electrode 166, and a diaphragm 176 has the above size relation, a minute thing is desirable [ the difference of a mutual area ], so that Mact can be computed from the thickness, the consistency, and area as the whole oscillating section. Moreover, as for parts other than the circular part which are those principal parts, in this example, it is desirable in the

piezo-electric layer 160, the up electrode 164, and the lower electrode 166 that it is so minute that it can ignore to the principal part. Therefore, in an actuator 106, Mact is the sum of each inertance of the up electrode 164, the lower electrode 166, the piezo-electric layer 160, and the oscillating field of the diaphragms 176. Moreover, Compliance Cact is the compliance of the part formed of the up electrode 164, the lower electrode 166, the piezo-electric layer 160, and the oscillating field of the diaphragms 176.
[0044] In addition, although drawing 2 (A), drawing 2 (B), drawing 2 (D), and drawing 2 (F) show the oscillating section of an actuator 106, and the equal circuit of a cavity 162, in these equal circuits, Cact shows the compliance of the oscillating section of an actuator 106. Cpzt, Celectrode1 and Celectrode2, and Cvib show the compliance of the piezo-electric layer 160 in the oscillating section, the up electrode 164, the lower electrode 166, and a diaphragm 176, respectively. Cact is expressed with the following formulas 3.
[0045]
1-/Cact=(1-/Cpzt) +(1-/Celectrode1) +(1-/Celectrode2)+ (1-/Cvib) (formula 3)
From a formula 2 and a formula 3, drawing 2 (A) can also be expressed like drawing 2 (B).
[0046] Compliance Cact expresses the volume which can receive a medium according to the deformation when putting a pressure on the unit area of the oscillating section. Moreover, Compliance Cact may say that it expresses the ease of carrying out of deformation.
[0047] A liquid is fully held in a liquid container and drawing 2 (C) shows the sectional view of the actuator 106 in case the liquid is filled around the oscillating field of an actuator 106. A liquid is fully held in a liquid container and M'max of drawing 2 (C) expresses the maximum of an addition inertance in case the liquid is filled around the oscillating field of an actuator 106. M' max is [0048].
M'max=(pi*rho/(2*k3)) * (2*(2*k*a) 3/(3*pi))/(pi*a 2) 2 (formula 4)
(a is [ the consistency of a medium and k of the radius of the oscillating section and rho ] the wave numbers.)
[0049] It is come out and expressed. In addition, a formula 4 is materialized when the radius a of the oscillating field of an actuator 106 is circular. Addition inertance M' is an amount which shows that the mass of the oscillating section is increasing seemingly according to an operation of the medium near the oscillating section. As shown in a formula 4, M'max changes with the radius a of the oscillating section, and the consistencies rho of a medium a lot.
[0050] The wave number k is k=2* pi*fact/c. (formula 5)
(fact is the resonance frequency of the oscillating section when the liquid is not touching.) c is the rate of the sound which spreads the inside of a medium.
[0051] It is come out and expressed.
[0052] A liquid is fully held in a liquid container and drawing 2 (D) shows the oscillating section of the actuator 106 in the case of being drawing 2 (C) with which the liquid is filled around the oscillating field of an actuator 106, and the equal circuit of a cavity 162.
[0053] Although the liquid of a liquid container is consumed and drawing 2 (E) does not have a liquid around the oscillating field of an actuator 106, in the cavity 162 of an actuator 106, the sectional view of the actuator 106 when the liquid remains is shown. A formula 4 is a formula showing the greatest inertance M'max determined from the consistency rho of ink etc., when the liquid is filled by the liquid container. It is [0054] when the liquid around the oscillating field of an actuator 106 becomes a gas or a vacuum on the other hand, the liquid in a liquid container having been consumed and a liquid remaining in a cavity 162. M'= rho*t/S (formula 6)
It can express. t is the thickness of the medium in connection with vibration. S is the area of the

oscillating field of an actuator 106. It is S=pi*a 2 when the radius a of this oscillating field is circular. Therefore, addition inertance M' follows a formula 4, when a liquid is fully held in a liquid container and the liquid is filled around the oscillating field of an actuator 106. On the other hand, a liquid is consumed, and a formula 6 is followed when the liquid around the oscillating field of an actuator 106 becomes a gas or a vacuum, a liquid remaining in a cavity 162.

[0055] Here, although the liquid of a liquid container is consumed and there is no liquid around the oscillating field of an actuator 106 like drawing 2 (E), addition inertance M' when the liquid remains in the cavity 162 of an actuator 106 is made into M'cav for convenience, and it distinguishes from addition inertance M'max in case the liquid is filled around the oscillating field of an actuator 106.

[0056] Although the liquid of a liquid container is consumed and drawing 2 (F) does not have a liquid around the oscillating field of an actuator 106, in the cavity 162 of an actuator 106, the oscillating section of the actuator 106 in the case of being drawing 2 (E) in which the liquid remains, and the equal circuit of a cavity 162 are shown.

[0057] Here, the parameters related to the condition of a medium are the consistency rho of a medium, and thickness [ of a medium ] t in a formula 6. When the liquid is fully held in the liquid container, a liquid contacts the oscillating section of an actuator 106, when the liquid is not fully held in the liquid container, a liquid remains inside a cavity or a gas or a vacuum contacts the oscillating section of an actuator 106. The surrounding liquid of an actuator 106 is consumed, if the addition inertance in the process which shifts to M'cav of drawing 2 (E) from M'max of drawing 2 (C) is made into M'var, since thickness t of the consistency rho of a medium and a medium changes, addition inertance M'var will change and resonance frequency fs will also change with the hold conditions of the liquid in a liquid container. Therefore, the existence of the liquid in a liquid container is detectable by specifying resonance frequency fs. When M'cav is expressed using a formula 6, depth d of a cavity is substituted for t of a formula 6, and it is [0058]. M'cav=rho*d/S (formula 7)

It becomes.

[0059] Moreover, since a consistency rho changes with differences in a presentation even if a medium is a liquid with which classes differ mutually, addition inertance M' changes and resonance frequency fs also changes. Therefore, the class of liquid is detectable by specifying resonance frequency fs. In addition, when either ink or air contacts and it is not intermingled in the oscillating section of an actuator 106, the difference of M' can be detected even if it calculates by the formula 4.

[0060] Drawing 3 (A) is a graph which shows relation with the resonance frequency fs of the amount of the ink in an ink tank, ink, and the oscillating section. Here, ink is explained as one example of a liquid. An axis of ordinate shows resonance frequency fs, and an axis of abscissa shows the amount of ink. When an ink presentation is fixed, resonance frequency fs rises with the fall of an ink residue.

[0061] When ink is fully held in an ink container and ink is filled around the oscillating field of an actuator 106, the maximum addition inertance M'max serves as a value expressed to a formula 4. On the other hand, ink is consumed, and when ink is not filled around the oscillating field of an actuator 106, a liquid remaining in a cavity 162, addition inertance M'var is computed by the formula 6 based on thickness t of a medium. t in a formula 6 can also detect the process in which ink is gradually consumed by being small in d (referring to drawing 1 (B)) of the cavity 162 of an actuator 106, namely, making a substrate 178 thin enough since it is the thickness of the

medium in connection with vibration (refer to drawing 2 (C)). Here, tink considers as the thickness of the ink in connection with vibration, and sets tink-max to tink in M'max. For example, an actuator 106 is arranged almost horizontally to the oil level of ink on the base of an ink cartridge. If ink is consumed and the oil level of ink reaches below the height of t from an actuator 106, M'var will change with formulas 6 gradually and resonance frequency fs will change with formulas 1 gradually. Therefore, as long as the oil level of ink is within the limits of t, as for an actuator 106, the consumption condition of ink is detectable gradually.

[0062] Moreover, according to the location of the oil level by consumption of ink, S in a formula 6 changes by making the oscillating field of an actuator 106 greatly or long, and arranging perpendicularly. Therefore, an actuator 106 can also detect the process in which ink is consumed gradually. For example, an actuator 106 is arranged almost perpendicularly to the oil level of ink on the side attachment wall of an ink cartridge. If ink is consumed and the oil level of ink arrives at the oscillating field of an actuator 106, since addition inertance M' will decrease with the fall of water level, resonance frequency fs increases gradually by the formula 1. Therefore, as for an actuator 106, the oil level of ink can detect the consumption condition of ink gradually, as long as it is within the limits of path 2a (refer to drawing 2 (C)) of a cavity 162.

[0063] The curve X of drawing 3 (A) expresses relation with the resonance frequency fs of the amount of the ink held in the ink tank the case where the cavity 162 of an actuator 106 is made shallow enough, and at the time of making the oscillating field of an actuator 106 greatly enough or long, ink, and the oscillating section. While the amount of the ink in an ink tank decreases, he can understand signs that the resonance frequency fs of ink and the oscillating section changes gradually.

[0064] The case where the process in which ink is consumed gradually is detectable in a detail is a case where both the liquids and gases from which a consistency differs mutually exist, and it is concerned with vibration, in the circumference of the oscillating field of an actuator 106 more. While liquids decrease in number, a gas increases the medium on the circumference of an oscillating field of an actuator 106, and in connection with vibration, as ink is consumed gradually. For example, it is the case where an actuator 106 is horizontally arranged to the oil level of ink, and when tink is smaller than tink-max, the medium in connection with vibration of an actuator 106 contains both ink and a gas. Therefore, it is [0065] when the condition of having become below M'max of a formula 4 when it was the area S of the oscillating field of an actuator 106 is expressed with the additional mass of ink and a gas.

M'=M'air+M'ink= rho air*tair/S+rho ink*tink/S (formula 8)

It becomes. Here, M'air is the inertance of air and M'ink is the inertance of ink. rhoair is the consistency of air and rhoink is the consistency of ink. tair is the thickness of the air in connection with vibration, and tink is the thickness of the ink in connection with vibration. When the actuator 106 is arranged almost horizontally to the oil level of ink as liquids decrease in number among the media in connection with the vibration in the circumference of an oscillating field of an actuator 106 and a gas increases, tair increases and tink decreases. By it, M'var decreases gradually and resonance frequency increases gradually. Therefore, the amount of the ink which remains in an ink tank, or the consumption of ink is detectable. In addition, in a formula 7, it is the formula of only the consistency of a liquid because the case of being so small that the consistency of air being disregarded is assumed to the consistency of a liquid.

[0066] When the actuator 106 is arranged almost perpendicularly to the oil level of ink, the media in connection with vibration of an actuator 106 are considered to be the field of only ink, and the equal circuit (not shown) of juxtaposition of the medium in connection with vibration of

an actuator 106 with a gaseous field among the oscillating fields of an actuator 106. It is [0067], when the medium in connection with vibration of an actuator 106 sets area of the field of only ink to Sink and the medium in connection with vibration of an actuator 106 sets area of a gaseous field to Sair.
1/M'=1/M'air+1/M'ink=Sair/(rhoair*tair) +Sink/(rhoink*tink) (formula 9)
It becomes.
[0068] In addition, a formula 9 is applied when ink is not held at the cavity of an actuator 106. About the case where ink is held at the cavity of an actuator 106, it is calculable with a formula 7, a formula 8, and a formula 9.
[0069] On the other hand, the oil level of ink will detect an upper location or a bottom location from the stowed position of an actuator rather than a substrate 178 is thick, namely, depth d of a cavity 162 is deep, and it detects the process in which ink decreases in number gradually in practice, when d uses an actuator with a very small oscillating field as compared with the case of being comparatively close to thickness tink-max of a medium, and the height of a liquid container. When it puts in another way, the existence of the ink in the oscillating field of an actuator will be detected. For example, the curve Y of drawing 3 (A) shows relation with the resonance frequency fs of the amount of the ink in the ink tank in the case of a small circular oscillating field, ink, and the oscillating section. Between the amounts Q of ink before and after the oil level of the ink in an ink tank passes through the stowed position of an actuator, signs that the resonance frequency fs of ink and the oscillating section is changing violently are shown. From this, it is detectable in an ink tank whether ink is carrying out specified quantity survival.
[0070] A diaphragm 176 is contacting a liquid and directly, and since the method of detecting the existence of a liquid using an actuator 106 detects the existence of ink, compared with the approach of calculating the consumption of ink with software, its detection precision is high. Furthermore, although the approach conductivity detects the existence of ink is influenced according to the attaching position to a liquid container, and the class of ink using an electrode, the approach of detecting the existence of a liquid using an actuator 106 is not influenced according to the attaching position to a liquid container, and the class of ink. Furthermore, since the both sides of detection of the existence of a liquid can be considered as an oscillation using the single actuator 106, the number of the sensors attached in a liquid container as compared with the approach of carrying out oscillation and detection of the existence of a liquid using a different sensor can be decreased. Therefore, a liquid container can be manufactured cheaply. Furthermore, it can be [ sound / which an actuator 106 generates working ] quiet by setting the oscillation frequency of the piezo-electric layer 160 as a non-audible field.
[0071] Drawing 3 (B) shows relation with the resonance frequency fs of the consistency of the ink in the curve Y of drawing 3 (A), ink, and the oscillating section. Ink is mentioned as an example of a liquid. Since an addition inertance will become large if an ink consistency becomes high as shown in drawing 3 (B), resonance frequency fs falls. That is, resonance frequency fs changes with classes of ink. Therefore, in case it is re-filled up with ink by measuring resonance frequency fs, it can check whether the ink in which consistencies differed is mixed.
[0072] That is, the ink tank which holds the ink in which classes differ mutually is discriminable.
[0073] Then, even if the liquid in a liquid container is the state of the sky, the conditions which can detect correctly the condition of a liquid when setting up the size and the configuration of a cavity so that a liquid may remain in the cavity 162 of an actuator 106 are explained in full detail. If the condition of a liquid can be detected when the liquid is filled in the cavity 162, an actuator 106 can detect the condition of a liquid, even if it is the case where the liquid is not

filled in the cavity 162.
[0074] Resonance frequency fs is a function of Inertance M. Inertance M is the sum of the inertance Mact of the oscillating section, and addition inertance M'. Here, addition inertance M' is related to the condition of a liquid. Addition inertance M' is an amount which shows that the mass of the oscillating section is increasing seemingly according to an operation of the medium near the oscillating section. That is, the increment of the mass of the oscillating section by absorbing a medium seemingly by vibration of the oscillating section is said.
[0075] Therefore, when M'cav is larger than M'max in a formula 4, all the media absorbed seemingly are liquids which remain in a cavity 162. Therefore, it is the same as the condition that the liquid is filled in the liquid container. In this case, since M' does not change, resonance frequency fs does not change, either. Therefore, an actuator 106 can detect the condition of the liquid in a liquid container.
[0076] On the other hand, when M'cav is smaller than M' max in a formula 4, the medium absorbed seemingly is the gas or vacuum in the liquid which remains in a cavity 162, and a liquid container. Since M' changes unlike the condition that the liquid is filled in the liquid container at this time, resonance frequency fs changes. Therefore, an actuator 106 can detect the condition of the liquid in a liquid container.
[0077] That is, the liquid in a liquid container is the state of the sky, and when a liquid remains in the cavity 162 of an actuator 106, the conditions on which an actuator 106 can detect the condition of a liquid correctly are that M'cav is smaller than M'max. In addition, condition M'max>M'cav to which an actuator 106 can detect the condition of a liquid correctly is not concerned with the configuration of a cavity 162.
[0078] Here, M'cav is the capacity of a cavity 162, and the mass of the liquid of an almost equal capacity. Therefore, an actuator 106 can express the conditions which can detect the condition of a liquid correctly as conditions for the capacity of a cavity 162 from the inequality of M'max>M'cav. For example, it is [0079], when the radius of the opening 161 of the cavity 162 of a circle configuration is set to a and the depth of a cavity 162 is set to d. M'max>rho*d/pi a2 (formula 10)
It comes out. It is [0080] when a formula 10 is developed. a/d>3*pi/8 (formula 11)
The conditions to say are searched for. In addition, when the configuration of a cavity 162 is circular, a formula 10 and a formula 11 are restricted and are materialized. If pia2 in a formula 10 is calculated by replacing it with the area using the formula of M'max when not being circular, the relation between dimensions, such as width of face of a cavity and die length, and the depth can be drawn.
[0081] Therefore, if it is the actuator 106 which has the cavity 162 which are the radius a of the opening 161 which fills a formula 11, and depth [ of a cavity 162 ] d, even if the liquid in a liquid container is the state of the sky and it is the case where a liquid remains in a cavity 162, the condition of a liquid can be detected, without incorrect-operating.
[0082] It can be said that the approach of measuring back EMF generated in an actuator 106 by residual vibration has detected change of an acoustic impedance at least since addition inertance M' also influences an acoustic-impedance property.
[0083] Moreover, according to this example, back EMF which an actuator 106 generates vibration and generates in an actuator 106 by subsequent residual vibration is measured. However, it is not necessarily required for the oscillating section of an actuator 106 to give vibration to a liquid by its vibration by driver voltage. That is, even if the oscillating section does not oscillate itself, the piezo-electric layer 160 bends and deforms by vibrating with the liquid of

a certain range in contact with it. This residual vibration makes the piezo-electric layer 160 generate the back EMF electrical potential difference, and transmits that back EMF electrical potential difference to the up electrode 164 and the lower electrode 166. The condition of a medium may be detected by using this phenomenon. For example, it may set to an ink jet recording apparatus, and the condition of an ink tank or the ink of the interior may be detected using vibration around the oscillating section of the actuator generated by vibration by the reciprocating motion of the carriage by the scan of the print head at the time of printing.
[0084] Drawing 4 (A) And drawing 4 (B) shows the wave of the residual vibration of an actuator 106 after vibrating an actuator 106, and the measuring method of residual vibration. the ink in the stowed position level of the actuator 106 in an ink cartridge -- the upper and lower sides of water level are detectable with frequency change of the residual vibration after an actuator 106 oscillates, and change of the amplitude. Drawing 4 (A) And in drawing 4 (B), an axis of ordinate shows the electrical potential difference of back EMF generated by the residual vibration of an actuator 106, and an axis of abscissa shows time amount. By the residual vibration of an actuator 106, it is drawing 4 R> 4 (A). And as shown in drawing 4 (B), the wave of the analog signal of an electrical potential difference occurs. Next, an analog signal is changed into the digital numeric value corresponding to the frequency of a signal.
[0085] Drawing 4 (A) And in the example shown in drawing 4 (B), the existence of ink is detected by measuring the time amount which four pulses to 8 pulse eye produce from 4 pulse eye of an analog signal.
[0086] More, in a detail, after an actuator 106 oscillates, the count which crosses the predetermined reference voltage set up beforehand from a low-battery side to a high-voltage side is counted. The between from four counts to eight counts is set to High for a digital signal, and the time amount from four counts to eight counts is measured by the predetermined clock pulse.
[0087] Drawing 4 (A) is a wave in case a liquid ink side is in a high order rather than the stowed position level of an actuator 106. On the other hand, drawing 4 (B) is a wave in case there is no ink in the stowed position level of an actuator 106. When drawing 4 R> 4 (A) is compared with drawing 4 (B), in drawing 4 (A), a ******** understands the time amount from four counts to eight counts from drawing 4 (B). A paraphrase changes the time amount from four counts to eight counts by the existence of ink. The consumption condition of ink is detectable using a difference of this time amount. After vibration of an actuator 106 is stabilized, it counts for beginning measurement from 4 count eye of an analog wave. What it was presupposed that it is from 4 count eye is a mere example, and may count from the count of arbitration. Here, the signal from 4 count eye to 8 count eye is detected, and the time amount from 4 count eye to 8 count eye is measured by the predetermined clock pulse. It asks for resonance frequency by it. As for a clock pulse, it is desirable that it is the pulse of a clock equal to the clock for controlling the semiconductor memory attached in an ink cartridge. In addition, there is no need of measuring the time amount to 8 count eye, and it may be counted to the count of arbitration. In drawing 4 , although the time amount from 4 count eye to 8 count eye is measured, according to the circuitry which detects a frequency, the time amount in a different counting interval may be detected.
[0088] For example, when fluctuation of the amplitude of a peak is small, in order the quality of ink is stable, and to gather the rate of detection, you may ask for resonance frequency by detecting the time amount from 4 count eye to 6 count eye. Moreover, the quality of ink is unstable, and when fluctuation of the amplitude of a pulse is large, in order to detect residual vibration correctly, the time amount from 4 count eye to 12 count eye may be detected.

[0089] Moreover, the wave number of the voltage waveform of back EMF within a predetermined period may be counted as other examples (not shown). It can ask for resonance frequency also by this approach. More, in a detail, after an actuator 106 oscillates, only a predetermined period sets a digital signal to High, and the count which crosses predetermined reference voltage from a low-battery side to a high-voltage side is counted. The existence of ink is detectable by measuring the number of counts.
[0090] Furthermore, the back EMF wave amplitudes differ by the case where there are not a case where ink is filled in the ink cartridge, and ink into an ink cartridge so that drawing 4 (A) and drawing 4 (B) may be compared and understood. Therefore, the consumption condition of the ink in an ink cartridge may be detected also by measuring the back EMF wave amplitude, without asking for resonance frequency. Top-most vertices and drawing 4 (B) of the back EMF wave [ detail ] of drawing 4 R> 4 (A) more Reference voltage is set up between the top-most vertices of the back EMF wave. When a digital signal is set to High at predetermined time and the back EMF wave crosses reference voltage after the actuator 106 oscillated, it is judged that there is no ink. When the back EMF wave does not cross reference voltage, it is judged that there is ink.
[0091] Drawing 5 shows the manufacture approach of an actuator 106. Two or more actuators 106 (the example of drawing 5 four pieces) are formed in one. The actuator 106 shown in drawing 6 is manufactured by cutting the one moldings of two or more actuators shown in drawing 5 in each actuator 106. When each piezoelectric device of two or more really shown [ in drawing 5 ] fabricated actuators 106 is circular, the actuator 106 shown in drawing 1 can be manufactured by really cutting a moldings in each actuator 106. By forming two or more actuators 106 in one, two or more actuators 106 can be efficiently manufactured to coincidence, and the handling at the time of conveyance becomes easy.
[0092] An actuator 106 has sheet metal or a diaphragm 176, a substrate 178, an elastic wave generating means or a piezoelectric device 174, a terminal formation member or the up electrode terminal 168 and a terminal formation member, or the lower electrode terminal 170. A piezoelectric device 174 contains a piezo-electric diaphragm or the piezo-electric layer 160, an upper electrode or the up electrode 164 and a bottom electrode, or the lower electrode 166. A diaphragm 176 is formed in the top face of a substrate 178, and the lower electrode 166 is formed in the top face of a diaphragm 176. The piezo-electric layer 160 is formed in the top face of the lower electrode 166, and the up electrode 164 is formed in the top face of the piezo-electric layer 160. Therefore, of the principal part of the up electrode 164, and the principal part of the lower electrode 166, the principal part of the piezo-electric layer 160 is formed so that it may be inserted from the upper and lower sides.
[0093] The piezoelectric device 174 of plurality (the example of drawing 5 four pieces) is formed on the diaphragm 176. The lower electrode 166 is formed in the front face of a diaphragm 176, the piezo-electric layer 160 is formed in the front face of the lower electrode 166, and the up electrode 164 is formed in the top face of the piezo-electric layer 160. The up electrode terminal 168 and the lower electrode terminal 170 are formed in the edge of the up electrode 164 and the lower electrode 166. Four actuators 106 are cut separately, respectively and are used according to an individual.
[0094] As for drawing 6 , a piezoelectric device shows some cross sections of the rectangular actuator 106.
[0095] Drawing 7 shows the cross section of the whole actuator 106 shown in drawing 6 . Through tube 178a is formed in the piezoelectric device 174 of a substrate 178, and the field

which counters. The closure of the through tube 178a is carried out by the diaphragm 176. A diaphragm 176 is equipped with electric insulation, such as an alumina and an oxidization zirconia, and is formed with the ingredient in which elastic deformation is possible. The piezoelectric device 174 is formed on the diaphragm 176 so that it may counter with through tube 178a. The lower electrode 166 is formed in the front face of a diaphragm 176 so that it may extend from the field of through tube 178a to the left in an one direction and drawing 7 . The up electrode 164 is formed in the front face of the piezo-electric layer 160 so that it may extend in the method of the right in drawing 7 in the direction opposite to a lower electrode from the field of through tube 178a. The up electrode terminal 168 and the lower electrode terminal 170 are formed in the top face of an auxiliary electrode 172 and the lower electrode 166, respectively. The lower electrode terminal 170 contacts the lower electrode 166 electrically, and the up electrode terminal 168 contacts the up electrode 164 electrically through an auxiliary electrode 172, and it delivers the signal between a piezoelectric device and the exterior of an actuator 106. The up electrode terminal 168 and the lower electrode terminal 170 have the height more than the height of the piezoelectric device which doubled the electrode and the piezo-electric layer.

[0096] Drawing 8 shows the manufacture approach of the actuator 106 shown in drawing 5 . First, a press or laser processing is used for a green sheet 940, and through tube 940a is punched. A green sheet 940 serves as a substrate 178 after baking. A green sheet 940 is formed with ingredients, such as a ceramic. Next, the laminating of the green sheet 941 is carried out to the front face of a green sheet 940. A green sheet 941 serves as a diaphragm 176 after baking. A green sheet 941 is formed with ingredients, such as an oxidization zirconia. Next, sequential formation of a conductive layer 942, the piezo-electric layer 160, and the conductive layer 944 is carried out by approaches, such as pressure membrane printing, on the front face of a green sheet 941. A conductive layer 942 serves as the lower electrode 166 behind, and a conductive layer 944 serves as the up electrode 164 behind. Next, the formed green sheet 940, a green sheet 941, a conductive layer 942, the piezo-electric layer 160, and a conductive layer 944 are dried and calcinated. Spacing members 947 and 948 carry out bottom raising of the height of the up electrode terminal 168 and the lower electrode terminal 170, and make it higher than a piezoelectric device. Spacing members 947 and 948 carry out the laminating of printing or the green sheet, and form green sheets 940 and 941 and this ingredient. Since there are few ingredients of the up electrode terminal 168 which is noble metals, and the lower electrode terminal 170, it ends upwards by this spacing member 947,948 and thickness of the up electrode terminal 168 and the lower electrode terminal 170 can be made thin, the up electrode terminal 168 and the lower electrode terminal 170 can be printed with a sufficient precision, and it can consider as the height stabilized further.

[0097] If connection 944' with a conductive layer 944 and spacing members 947 and 948 are formed in coincidence at the time of formation of a conductive layer 942, the up electrode terminal 168 and the lower electrode terminal 170 can be formed easily, or it can fix firmly. Finally, the up electrode terminal 168 and the lower electrode terminal 170 are formed in the edge field of a conductive layer 942 and a conductive layer 944. In case the up electrode terminal 168 and the lower electrode terminal 170 are formed, it forms so that the up electrode terminal 168 and the lower electrode terminal 170 may be electrically connected to the piezo-electric layer 160.

[0098] Drawing 9 shows the operation gestalt of further others of the ink cartridge to which this invention is applied. Drawing 9 (A) is the sectional view of the pars basilaris ossis occipitalis of the ink cartridge by this operation gestalt. The ink cartridge of this operation gestalt has through

tube 1c in base 1a of a container 1 which holds ink. The pars basilaris ossis occipitalis of through tube 1c is closed by the actuator 650, and forms an ink reservoir.
[0099] Drawing 9 (B) shows the actuator 650 shown in drawing 9 (A), and the detailed cross section of through tube 1c. Drawing 9 R> 9 (C) shows the flat surface of the actuator 650 shown in drawing 9 (B), and through tube 1c. An actuator 650 has the piezoelectric device 73 fixed to the diaphragm 72 and the diaphragm 72. An actuator 650 is fixed to the base of a container 1 so that a piezoelectric device 73 may counter through tube 1c through a diaphragm 72 and a substrate 71. Elastic deformation is possible for a diaphragm 72, and it is equipped with ink-proof nature.
[0100] Depending on the amount of ink of a container 1, the amplitude and frequency of back EMF which are generated by the residual vibration of a piezoelectric device 73 and a diaphragm 72 change. Through tube 1c is formed in the location which counters an actuator 650, and the ink of the minimum constant rate is secured to through tube 1c. Therefore, the ink end of a container 1 is certainly detectable by measuring beforehand the property of vibration of the actuator 650 decided by the amount of ink secured to through tube 1c.
[0101] Drawing 10 shows other operation gestalten of through tube 1c. In each of drawing 10 (A), (B), and (C), the condition that the chart on the left does not have Ink K in through tube 1c is shown, and right-hand side drawing shows the condition that Ink K remained in through tube 1c. In the operation gestalt of drawing 9 , the side face of through tube 1c is formed as a perpendicular wall. In drawing 10 (A), 1d of side faces of through tube 1c is slanting in the vertical direction, and it is expanded and opened outside. In drawing 10 (B), the level difference sections 1e and 1f are formed in the side face of through tube 1c. 1f of level difference sections which are up is larger than level difference section 1e which exists caudad. In drawing 10 (C), through tube 1c has 1g of slots which extend in the direction of the ink feed hopper 2 which is easy to discharge Ink K, i.e., the direction.
[0102] Drawing 10 (A) According to the configuration of through tube 1c shown in - (C), the amount of the ink K of an ink reservoir can be lessened. Therefore, since the oscillation characteristic of the ink and the actuator 650 at the time since M'cav explained by drawing 1 and drawing 2 can be made small as compared with M'max can be greatly changed with the case where the ink K of the amount which can be printed in a container 1 remains, an ink end can be detected more certainly.
[0103] Drawing 11 is the perspective view showing other operation gestalten of an actuator. An actuator 660 has packing 76 outside through tube 1c of the substrate which constitutes an actuator 660, or the attachment plate 78. The caulking hole 77 is formed in the periphery of an actuator 660. An actuator 660 is fixed to a container 1 with caulking through the caulking hole 77.
[0104] Drawing 12 (A) and (B) are the perspective views showing the operation gestalt of further others of an actuator. An actuator 670 is equipped with the crevice formation substrate 80 and a piezoelectric device 82 in this operation gestalt. A crevice 81 is formed in one field of the crevice formation substrate 80 of technique, such as etching, and a piezoelectric device 82 is attached in the field of another side. The pars basilaris ossis occipitalis of a crevice 81 acts as an oscillating field among the crevice formation substrates 80. Therefore, the oscillating field of an actuator 670 is specified by the periphery of a crevice 81. Moreover, an actuator 670 is similar with the structure where the substrate 178 and the diaphragm 176 were formed as one among the actuators 106 by the example of drawing 1 . Therefore, in case an ink cartridge is manufactured, a production process can be shortened, and cost is reduced. An actuator 670 is size in which

embedding is possible to through tube 1c prepared in the container 1. By it, a crevice 81 can act also as a cavity. In addition, like the actuator 670 by the example of drawing 12 , the actuator 106 by the example of drawing 1 may be formed in through tube 1c so that embedding may be possible.

[0105] Drawing 13 is the perspective view showing the configuration which attached the actuator 106 and was really formed as a module object 100. The predetermined part of the container 1 of an ink cartridge is equipped with the module object 100. By [ in liquid ink ] detecting change of an acoustic impedance at least, the module object 100 is constituted so that the consumption condition of the liquid in a container 1 may be detected. The module object 100 of this operation gestalt has the liquid-container attachment section 101 for attaching an actuator 106 in a container 1. The liquid-container attachment section 101 has structure with which the flat surface carried the cylinder section 116 which held the actuator 106 oscillated with a driving signal on the rectangular pedestal 102 mostly. Since it is constituted so that the actuator 106 of the module object 100 cannot contact from the outside when an ink cartridge is equipped with the module object 100, an actuator 106 can be protected from external contact. In addition, the radius of circle is attached, and in case the hole formed in the ink cartridge is equipped, it is easy to insert in the tip side edge of the cylinder section 116.

[0106] Drawing 14 is the exploded view showing the configuration of the module object 100 shown in drawing 13 . The module object 100 contains the liquid-container attachment section 101 which consists of resin, and the piezoelectric device applied part 105 which has a plate 110 and a crevice 113. Furthermore, the module object 100 has reed wires 104a and 104b, an actuator 106, and a film 108. Preferably, a plate 110 is formed from ingredients which cannot rust easily, such as stainless steel or a stainless alloy. Opening 114 is formed in a core so that the cylinder section 116 and the pedestal 102 which are included in the liquid-container attachment section 101 can hold reed wires 104a and 104b, and a crevice 113 is formed so that an actuator 106, a film 108, and a plate 110 can be held. An actuator 106 is joined to a plate 110 through a film 108, and a plate 110 and an actuator 106 are fixed to the liquid-container attachment section 101. Therefore, reed wires 104a and 104b, an actuator 106, a film 108, and a plate 110 are attached in the liquid-container attachment section 101 as one. Reed wires 104a and 104b combine with the up electrode of an actuator 106, and a lower electrode, respectively, transmit a driving signal to a piezo-electric layer, and, on the other hand, transmit the signal of the resonance frequency which the actuator 106 detected to a recording device etc. An actuator 106 is temporarily oscillated based on the driving signal transmitted from reed wires 104a and 104b. Residual vibration of the actuator 106 is carried out after an oscillation, and it generates back EMF by the vibration. At this time, the resonance frequency corresponding to the consumption condition of the liquid in a liquid container is detectable by detecting the period of vibration of the back EMF wave. a film 108 -- an actuator 106 and a plate 110 -- pasting up -- an actuator -- liquid -- it is made dense. As for a film 108, it is desirable to form with polyolefine etc. and to paste up by thermal melting arrival. a film 108 -- an actuator 106 and a plate 110 -- pasting up -- an actuator -- liquid -- it is made dense. As for a film 108, it is desirable to form with polyolefine and to paste up by thermal melting arrival. By pasting up an actuator 106 and a plate 110 in the shape of a field with a film 108, and fixing, dispersion by the location of adhesion is lost and any parts other than the oscillating section do not vibrate. Therefore, change of the resonance frequency of the back before pasting up an actuator 106 on a plate 110 is small.

[0107] A plate 110 is a circle configuration and the opening 114 of a pedestal 102 is formed in the shape of a cylinder. The actuator 106 and the film 108 are formed in the shape of a rectangle.

A reed wire 104, an actuator 106, a film 108, and a plate 110 are good also as removable to a pedestal 102. A pedestal 102, the reed wire 104, the actuator 106, the film 108, and the plate 110 are arranged to the medial axis of the module object 100 at the symmetry. furthermore, the core of a pedestal 102, an actuator 106, a film 108, and a plate 110 -- the module object 100 -- it is mostly arranged on the medial axis.

[0108] The area of the opening 114 of a pedestal 102 is formed more greatly than the area of the oscillating field of an actuator 106. The through tube 112 is formed in the location which faces the oscillating section of an actuator 106 at the core of a plate 110. As shown in drawing 1 and drawing 2 , a cavity 162 is formed in an actuator 106, and both a through tube 112 and the cavity 162 form an ink reservoir. In order to lessen effect of residual ink, compared with the path of a through tube 112, the small thing of the thickness of a plate 110 is desirable. For example, as for the depth of a through tube 112, it is desirable that it is 1/3 or less magnitude of the path. a through tube 112 is the symmetry to the medial axis of the module object 100 -- it is the configuration of a perfect circle mostly. Moreover, the area of a through tube 112 is larger than the opening area of the cavity 162 of an actuator 106. The periphery of the cross section of a through tube 112 may be a taper configuration, and a step configuration is sufficient as it. The flank of a container 1, the upper part, or a pars basilaris ossis occipitalis is equipped with the module object 100 so that a through tube 112 may turn to the inside of a container 1. If ink is consumed and the ink of the actuator 106 circumference is lost, since the resonance frequency of an actuator 106 will change a lot, at least the water of ink can detect change.

[0109] Drawing 15 is the perspective view showing other operation gestalten of a module object. As for the module object 400 of this operation gestalt, the piezoelectric device applied part 405 is formed in the liquid-container attachment section 401. As for the liquid-container attachment section 401, the cylinder-like cylinder section 403 is mostly formed for the flat surface on the pedestal 402 on Kakumaru's square. Furthermore, the piezoelectric device applied part 405 includes the tabular element 406 and crevice 413 which were stood on the cylinder section 403. An actuator 106 is arranged in the crevice 413 established in the side face of the tabular element 406. In addition, the tip of the tabular element 406 is beveled by the predetermined include angle, and in case the hole formed in the ink cartridge is equipped, it is easy to insert it in.

[0110] Drawing 16 is the decomposition perspective view showing the configuration of the module object 400 shown in drawing 15 . The module object 400 as well as the module object 100 shown in drawing 13 contains the liquid-container attachment section 401 and the piezoelectric device applied part 405. The liquid-container attachment section 401 has a pedestal 402 and the cylinder section 403, and the piezoelectric device applied part 405 has the tabular element 406 and a crevice 413. It is joined to a plate 410 and an actuator 106 is fixed to a crevice 413. The module object 400 has further reed wires 404a and 404b, an actuator 106, and a film 408.

[0111] According to this operation gestalt, a plate 410 is a rectangle-like and the opening 414 prepared in the tabular element 406 is formed in the shape of a rectangle. Reed wires 404a and 404b, an actuator 106, a film 408, and a plate 410 may be constituted as removable to a pedestal 402. An actuator 106, a film 408, and a plate 410 pass along the core of opening 414, and are arranged at the symmetry to the medial axis prolonged in the direction of a vertical to the flat surface of opening 414. furthermore, the core of an actuator 406, a film 408, and a plate 410 -- opening 414 -- it is mostly arranged on the medial axis.

[0112] The area of the through tube 412 prepared in the core of a plate 410 is formed more greatly than the area of opening of the cavity 162 of an actuator 106. Both the cavities 162 and

through tubes 412 of an actuator 106 form an ink reservoir. The thickness of a plate 410 is small compared with the path of a through tube 412, for example, it is desirable to set it as 1/3 or less magnitude of the path of a through tube 412. a through tube 412 is the symmetry to the medial axis of the module object 400 -- it is the configuration of a perfect circle mostly. The periphery of the cross section of a through tube 412 may be a taper configuration, and a step configuration is sufficient as it. The pars basilaris ossis occipitalis of a container 1 can be equipped with the module object 400 so that a through tube 412 may be arranged inside a container 1. Since it is arranged in a container 1 so that an actuator 106 may be prolonged perpendicularly, a setup at the time of an ink end is easily changeable by changing the height which changes the height of a pedestal 402 and by which an actuator 106 is arranged in a container 1.

[0113] Drawing 17 shows the operation gestalt of further others of a module object. The module object 500 of drawing 17 as well as the module object 100 shown in drawing 13 contains the liquid-container attachment section 501 which has a pedestal 502 and the cylinder section 503. Moreover, the module object 500 has further reed wires 504a and 504b, an actuator 106, a film 508, and a plate 510. Opening 514 is formed in a core so that the pedestal 502 included in the liquid-container attachment section 501 can hold reed wires 504a and 504b, and a crevice 513 is formed so that an actuator 106, a film 508, and a plate 510 can be held. PUAKUCHUETA 106 is fixed to the piezoelectric device applied part 505 through a plate 510. Therefore, reed wires 504a and 504b, an actuator 106, a film 508, and a plate 510 are attached in the liquid-container attachment section 501 as one. As for the module object 500 of this operation gestalt, the cylinder section 503 with a top face slanting in the vertical direction is mostly formed for the flat surface on the pedestal on Kakumaru's square. The actuator 106 is arranged on the crevice 513 aslant prepared in the vertical direction of the top face of the cylinder section 503.

[0114] The tip of the module object 500 inclines and the inclined plane is equipped with the actuator 106. Therefore, if the pars basilaris ossis occipitalis or flank of a container 1 is equipped with the module object 500, an actuator 106 inclines to the vertical direction of a container 1. As for whenever [ tilt-angle / of the tip of the module object 500 ], it is desirable to consider as for about 30 to 60 degrees in view of detectability ability.

[0115] The pars basilaris ossis occipitalis or flank of a container 1 is equipped with the module object 500 so that an actuator 106 may be arranged in a container 1. When the flank of a container 1 is equipped with the module object 500, it is attached in a container 1, an actuator 106 inclining so that a container 1 top, bottom, or width side may be turned to. It is desirable that it is attached in a container 1 on the other hand, an actuator 106 inclining so that the ink feed hopper side of a container 1 may be turned to when the pars basilaris ossis occipitalis of a container 1 is equipped with the module object 500.

[0116] Drawing 18 is a sectional view near the pars basilaris ossis occipitalis of the ink container when equipping a container 1 with the module object 100 shown in drawing 13 . It is equipped with the module object 100 so that the side attachment wall of a container 1 may be penetrated. O ring 365 is formed in the plane of composition of the side attachment wall of a container 1, and the module object 100, and **** of the module object 100 and a container 1 is maintained at it. It is desirable to have the cylinder section which the module object 100 explained that a seal is made with an O ring by drawing 13 . By the tip of the module object 100 being inserted in the interior of a container 1, the ink in a container 1 contacts an actuator 106 through the through tube 112 of a plate 110. Since the resonance frequency of the residual vibration of an actuator 106 changes with a liquid or gases, the perimeter of the oscillating section of an actuator 106 can detect the consumption condition of ink using the module object 100. Moreover, a container 1

may be equipped with the module objects 700A, 700B, 750A, and 750B shown in the module object 400 shown not only in the module object 100 but in drawing 15 , the module object 500 shown in drawing 17 R> 7 or drawing 19 , and drawing 20 , and the mold structure 600, and the existence of ink may be detected.

[0117] Drawing 19 shows the operation gestalt of further others of the module object 100. Module object 750A of drawing 19 (A) has an actuator 106 and a pedestal 360. The container 1 is equipped with module object 750A so that a front face may turn into an inside of the side attachment wall of a container 1, and the same field. An actuator 106 contains the piezo-electric layer 160, the up electrode 164, the lower electrode 166, and a diaphragm 176. The lower electrode 166 is formed in the top face of a diaphragm 176. The piezo-electric layer 160 is formed in the top face of the lower electrode 166, and the up electrode 164 is formed in the top face of the piezo-electric layer 160. Therefore, the piezo-electric layer 160 is formed so that it may be inserted from the upper and lower sides with the up electrode 164 and the lower electrode 166. The piezo-electric layer 160, the up electrode 164, and the lower electrode 166 form a piezoelectric device. A piezoelectric device is formed on a diaphragm 176. A piezoelectric device and the oscillating field of a diaphragm 176 are the oscillating sections in which an actuator actually vibrates. The through tube 385 is formed in the side attachment wall of a container 1. Therefore, ink contacts a diaphragm 176 through the through tube 385 of a container 1.

[0118] Next, the actuation of module object 750A shown in drawing 19 (A) is explained. The up electrode 164 and the lower electrode 166 transmit a driving signal to the piezo-electric layer 160, and transmit the signal of the resonance frequency which the piezo-electric layer 160 detected to a recording device. It oscillates with the driving signal transmitted with the up electrode 164 and the lower electrode 166, and residual vibration of the piezo-electric layer 160 is carried out. The piezo-electric layer 160 generates back EMF by this residual vibration. The period of vibration of the back EMF wave is counted, and the existence of ink can be detected by detecting the resonance frequency in the time. A container 1 is equipped only with a diaphragm 176 so that module object 750A may contact the ink in the ink container 1 in the field where an actuator 106 is opposite to the piezoelectric-device side of the oscillating section of an actuator 106, i.e., drawing 19 , (A). Module object 750A of drawing 19 (A) becomes unnecessary [ the embedding to the module object 100 of the electrode of reed wires 104a, 104b, 404a, 404b, 504a and 504b shown in drawing 17 from drawing 13 ]. Therefore, a forming cycle is simplified. Furthermore, it becomes exchangeable [ module object 750A ], and becomes recyclable. Furthermore, since the actuator 106 is protected by the pedestal 360, it can protect an actuator 106 from contact outside.

[0119] Drawing 19 (B) shows the operation gestalt of further others of module object 750B. Module object 750B of drawing 19 (B) has an actuator 106 and a pedestal 360. The container 1 is equipped with module object 750B so that a front face may turn into an inside of the side attachment wall of a container 1, and the same field. An actuator 106 contains the piezo-electric layer 160, the up electrode 164, the lower electrode 166, and a diaphragm 176. The lower electrode 166 is formed in the top face of a diaphragm 176. The piezo-electric layer 160 is formed in the top face of the lower electrode 166, and the up electrode 164 is formed in the top face of the piezo-electric layer 160. Therefore, the piezo-electric layer 160 is formed so that it may be inserted from the upper and lower sides with the up electrode 164 and the lower electrode 166. The piezo-electric layer 160, the up electrode 164, and the lower electrode 166 form a piezoelectric device. A piezoelectric device is formed on a diaphragm 176. A

piezoelectric device and the oscillating field of a diaphragm 176 are the oscillating sections in which an actuator actually vibrates. The thin wall 380 is formed in the side attachment wall of a container 1. A container 1 is equipped only with a diaphragm 176 so that module object 750B may contact the thin wall 380 of the ink container 1 in the field where an actuator 106 is opposite to the piezoelectric-device side of the oscillating section of an actuator 106, i.e., drawing 19 , (B). Therefore, residual vibration of the oscillating section of an actuator 106 is carried out with the thin wall 380.

[0120] Next, the actuation of module object 750B shown in drawing 19 (B) is explained. The up electrode 164 and the lower electrode 166 transmit a driving signal to the piezo-electric layer 160, and transmit the signal of the resonance frequency which the piezo-electric layer 160 detected to a recording device. It oscillates with the driving signal transmitted with the up electrode 164 and the lower electrode 166, and the piezo-electric layer 160 vibrates with a resonant period. Since the thin wall 380 of a container 1 is contacted, a diaphragm 176 carries out residual vibration of the oscillating section of an actuator 106 with the thin wall 380. Since the inside side of the container 1 of the thin wall 380 contacts ink, in case an actuator 106 carries out residual vibration with the thin wall 380, the resonance frequency and the amplitude of this residual vibration change with ink residues. The piezo-electric layer 160 generates back EMF by this residual vibration. The period of vibration of the back EMF wave can be counted, and an ink residue can be detected by detecting the resonance frequency at that time.

[0121] Module object 750B of drawing 19 (B) becomes unnecessary [ the embedding to the module object 100 of the electrode of reed wires 104a, 104b, 404a, 404b, 504a, and 504b shown in drawing 17 from drawing 13 ]. Therefore, a forming cycle is simplified. Furthermore, it becomes exchangeable [ module object 750B ], and becomes recyclable. Furthermore, since the actuator 106 is protected by the pedestal 360, it can protect an actuator 106 from contact outside.

[0122] Drawing 20 (A) shows the sectional view of the ink container when equipping a container 1 with module object 700B. In this example, module object 700B is used as one of the attachment structures. The container 1 is equipped with module object 700B as the liquid-container attachment section 360 projects inside a container 1. A through tube 370 is formed in the attachment plate 350, and the oscillating section of a through tube 370 and an actuator 106 faces. Furthermore, a hole 382 is formed in the bottom wall of module object 700B, and the piezoelectric device applied part 363 is formed. As an actuator 106 closes one side of a hole 382, it is arranged. Therefore, ink contacts a diaphragm 176 through the hole 382 of the piezoelectric device applied part 363, and the through tube 370 of the attachment plate 350. Both the hole 382 of the piezoelectric device applied part 363 and the through tube 370 of the attachment plate 350 form an ink reservoir. The piezoelectric device applied part 363 and the actuator 106 are being fixed by the attachment plate 350 and the film member. The sealing structure 372 is formed in the connection of the liquid-container attachment section 360 and a container 1. The sealing structure 372 may be formed with reversible ingredients, such as synthetic resin, and may be formed with an O ring. although module object 700B of drawing 20 (A) and a container 1 are another objects -- drawing 20 (B) -- the piezoelectric device applied part of module object 700B may consist of some containers 1 like.

[0123] Module object 700B of drawing 20 (A) becomes unnecessary [ the embedding to the module object of a reed wire shown in drawing 17 from drawing 13 ]. Therefore, a forming cycle is simplified. Furthermore, it becomes exchangeable [ module object 700B ], and becomes recyclable.

[0124] In case an ink cartridge shakes, an actuator 106 may incorrect-operate because the ink

which ink adhered to the top face or side face of a container 1, and has hung down from the top face or side face of a container 1 contacts an actuator 106. However, since the liquid-container attachment section 360 has projected module object 700B inside the container 1, an actuator 106 does not incorrect-operate in the ink which has hung down from the top face and side face of a container 1.

[0125] Moreover, in the example of drawing 20 (A), a container 1 is equipped with some of diaphragms 176 and attachment plates 350 so that the ink in a container 1 may be contacted. In the example of drawing 20 (A), the embedding to the module object of the electrode of reed wires 104a, 104b, 404a, 404b, 504a, and 504b shown in drawing 17 from drawing 13 becomes unnecessary. Therefore, a forming cycle is simplified. Furthermore, it becomes exchangeable [ an actuator 106 ] and becomes recyclable.

[0126] Drawing 20 (B) shows the sectional view of an ink container as an example when equipping a container 1 with an actuator 106. In the ink cartridge by the example of drawing 20 (B), the protection member 361 is attached in the container 1 as another object in the actuator 106. Therefore, although the protection member 361 and the actuator 106 are not united as a module, they are one side, and the protection member 361 can protect them so that a user's hand cannot be touched at an actuator 106. The hole 380 prepared in the front face of an actuator 106 is arranged by the side attachment wall of a container 1. An actuator 106 contains the piezo-electric layer 160, the up electrode 164, the lower electrode 166, a diaphragm 176, and the attachment plate 350. A diaphragm 176 is formed in the top face of the attachment plate 350, and the lower electrode 166 is formed in the top face of a diaphragm 176. The piezo-electric layer 160 is formed in the top face of the lower electrode 166, and the up electrode 164 is formed in the top face of the piezo-electric layer 160. Therefore, the principal part of the piezo-electric layer 160 is formed so that it may be inserted by the principal part of the up electrode 164, and the principal part of the lower electrode 166 from the upper and lower sides. The circular part which is each principal part of the piezo-electric layer 160, the up electrode 164, and the lower electrode 166 forms a piezoelectric device. A piezoelectric device is formed on a diaphragm 176. A piezoelectric device and the oscillating field of a diaphragm 176 are the oscillating sections in which an actuator actually vibrates. The through tube 370 is formed in the attachment plate 350. Furthermore, the hole 380 is formed in the side attachment wall of a container 1. Therefore, ink contacts a diaphragm 176 through the hole 380 of a container 1, and the through tube 370 of the attachment plate 350. Both the hole 380 of a container 1 and the through tube 370 of the attachment plate 350 form an ink reservoir. Moreover, in the example of drawing 20 (B), since the actuator 106 is protected by the protection member 361, it can protect an actuator 106 from contact outside.

[0127] In addition, it may replace with drawing 20 (A) and the attachment plate 350 in the example of (B), and the substrate 178 of drawing 1 may be used.

[0128] Drawing 20 (C) shows an operation gestalt equipped with the mold structure 600 containing an actuator 106. In this example, the mold structure 600 is used as one of the attachment structures. The mold structure 600 has an actuator 106 and the mold section 364. An actuator 106 and the mold section 364 are fabricated by one. The mold section 364 is fabricated with reversible ingredients, such as silicon resin. The mold section 364 has a reed wire 362 inside. The mold section 364 is formed so that it may have two guide pegs prolonged from an actuator 106. the mold section 364 -- the mold section 364 and a container 1 -- liquid -- since it fixes densely, the edge of two guide pegs of the mold section 364 is formed in the shape of a semi-sphere. A container 1 is equipped with the mold section 364 so that an actuator 106 may

project inside a container 1, and the oscillating section of an actuator 106 contacts the ink in a container 1. The up electrode 164, the piezo-electric layer 160, and the lower electrode 166 of an actuator 106 are protected from ink by the mold section 364.

[0129] For the mold structure 600 of drawing 20 (C), since the sealing structure 372 is unnecessary between the mold section 364 and a container 1, ink is a pile to the leakage from a container 1. Moreover, since it is the gestalt in which the mold structure 600 does not project from the exterior of a container 1, an actuator 106 can be protected from contact outside. In case an ink cartridge shakes, an actuator 106 may incorrect-operate because the ink which ink was attached to the top face or side face of a container 1, and has hung down from the top face or side face of a container 1 contacts an actuator 106. Since the mold section 364 has projected the mold structure 600 inside the container 1, an actuator 106 does not incorrect-operate in the ink which has hung down from the top face and side face of a container 1.

[0130] Drawing 21 shows the operation gestalt of the ink cartridge and ink jet recording device using the actuator 106 shown in drawing 1 . The ink jet recording device which has two or more ink induction 182 and electrode holders 184 corresponding to each ink cartridge 180 is equipped with two or more ink cartridges 180. Two or more ink cartridges 180 hold the ink of a class different, respectively, for example, a color. Each base of two or more ink cartridges 180 is equipped with the actuator 106 which is a means to detect an acoustic impedance at least. By equipping an ink cartridge 180 with an actuator 106, the ink residue in an ink cartridge 180 is detectable.

[0131] Drawing 22 shows the detail of the head section circumference of an ink jet recording device. An ink jet recording device has the ink induction 182, an electrode holder 184, the head plate 186, and a nozzle plate 188. Two or more formation of the nozzle 190 which injects ink is carried out at the nozzle plate 188. The ink induction 182 has the air supply opening 181 and the ink inlet 183. The air supply opening 181 supplies air to an ink cartridge 180. The ink inlet 183 introduces ink from an ink cartridge 180. An ink cartridge 180 has an air induction inlet 185 and the ink feed hopper 187. An air induction inlet 185 introduces air from the air supply opening 181 of the ink induction 182. The ink feed hopper 187 supplies ink to the ink inlet 183 of the ink induction 182. When an ink cartridge 180 introduces air from the ink induction 182, supply of the ink from the ink cartridge 180 to the ink induction 182 is urged. An electrode holder 184 opens for free passage the ink supplied through the ink induction 182 from the ink cartridge 180 on the head plate 186.

[0132] Drawing 23 shows other operation gestalten of an ink cartridge 180 shown in drawing 20 . Base 194a by which ink cartridge 180A of drawing 23 (A) was aslant formed in the vertical direction is equipped with the actuator 106. Inside the ink container 194 of an ink cartridge 180, the breaking-the-water wall 192 is formed in the actuator 106 of predetermined height, and the faced location from the internal base of the ink container 194. Since it is aslant equipped with the actuator 106 to the vertical direction of the ink container 194, it becomes the ****** fitness of ink.

[0133] The gap filled with ink is formed between an actuator 106 and the breaking-the-water wall 192. Moreover, spacing of the breaking-the-water wall 192 and an actuator 106 is vacated for extent with which ink is not held according to the capillary tube force. When the ink container 194 rolls, the wave of ink occurs in the ink container 194 interior by rolling, a gas and air bubbles are detected by the impact with an actuator 106, and an actuator 106 may incorrect-operate by it. By establishing the breaking-the-water wall 192, the wave of the ink of the actuator 106 neighborhood can be prevented and incorrect actuation of an actuator 106 can be prevented.

[0134] It is equipped with the actuator 106 of ink cartridge 180B of drawing 23 (B) on the side attachment wall of the feed hopper of the ink container 194. As long as it is near the ink feed hopper 187, the side attachment wall or base of the ink container 194 may be equipped with an actuator 106. Moreover, as for an actuator 106, it is desirable that the core of the cross direction of the ink container 194 is equipped. Since ink passes the ink feed hopper 187 and is supplied outside, ink and an actuator 106 contact certainly to an ink near end time by forming an actuator 106 near the ink feed hopper 187. Therefore, an actuator 106 can detect the time of an ink near end certainly.
[0135] Furthermore, by forming an actuator 106 near the ink feed hopper 187, in case the cartridge holder on carriage is equipped with an ink container, positioning with the actuator 106 on an ink container and the contact on carriage becomes certain. In connection on an ink container and carriage, positive association with an ink feed hopper and a supply needle is the most important for the reason. It is because its tip of a supply needle is hurt, or a damage will be given to sealing structures, such as an O ring, and ink will begin to leak, if there is a gap. In order to prevent such a trouble, the ink jet printer usually has the special structure which can do exact alignment, when mounting an ink container on carriage. Therefore, by arranging an actuator near the feed hopper, the alignment of an actuator also becomes a positive thing at coincidence. Furthermore, alignment can be more certainly carried out by equipping the core of the cross direction of the ink container 194 with an actuator 106. When an ink container carries out axial rocking a core [ a crosswise center line ] at the time of wearing to a holder, it is because there are few the shakes.
[0136] Drawing 24 shows the operation gestalt of further others of an ink cartridge 180. The sectional view which expanded side-attachment-wall 194b of ink cartridge 180C which showed drawing 24 (A) in the sectional view of ink cartridge 180C, and showed drawing 24 (B) to drawing 24 (A), and drawing 24 (C) are the perspective drawing from the transverse plane. Ink cartridge 180C is formed on the circuit board 610 with same semi-conductor storage means 7 and actuator 106. As shown in drawing 24 (B) and (C), the semi-conductor storage means 7 is formed above the circuit board 610, and the actuator 106 is formed under the semi-conductor storage means 7 in the same circuit board 610. Side-attachment-wall 194b is equipped with variant O ring 614 so that the perimeter of an actuator 106 may be surrounded. Two or more formation of the caulking section 616 for joining the circuit board 610 to the ink container 194 is carried out at side-attachment-wall 194b. while the oscillating field of an actuator 106 can be made to perform contacting ink by joining the circuit board 610 to the ink container 194, and pushing variant O ring 614 against the circuit board 610 by the caulking section 616 -- the exterior and the interior of an ink cartridge -- liquid -- it is kept dense.
[0137] The terminal 612 is formed in the semi-conductor storage means 7 and semi-conductor storage means 7 neighborhood. A terminal 612 delivers the signal between the semi-conductor storage means 7 and the exteriors, such as ink jet storage. The semi-conductor storage means 7 may be constituted by the rewritable semiconductor memory of EEPROM etc. On the same circuit board 610, since it is, the semi-conductor storage means 7 and an actuator 106 end like 1 time of a shipfitter, formation, now in case an actuator 106 and the semi-conductor storage means 7 are attached in ink cartridge 180C. Moreover, the routing at the time of manufacture of ink cartridge 180C and recycle is simplified. Furthermore, since the mark of components are reduced, the manufacturing cost of ink cartridge 180C can be reduced.
[0138] An actuator 106 detects the consumption condition of the ink in the ink container 194. The semi-conductor storage means 7 stores the information on ink, such as an ink residue which

the actuator 106 detected. That is, the semi-conductor storage means 7 stores the information about property parameters, such as the property of the ink used in case it detects, and an ink cartridge. The semi-conductor storage means 7 stores the resonance frequency of the time of an end, at i.e., the that the ink in the ink container 194 was consumed time, as one of the property parameters, when the ink in the ink container 194 is full beforehand (i.e., when ink is filled in the ink container 194). The ink in the ink container 194 may be stored when, as for the resonance frequency of full or an end condition, an ink jet recording device is equipped with an ink container for the first time. Moreover, as for the resonance frequency of full or an end condition, the ink in the ink container 194 may be stored during manufacture of the ink container 194. Resonance frequency in case the ink in the ink container 194 is full or an end beforehand is stored in the semi-conductor storage means 7, and since dispersion at the time of detecting an ink residue by reading the data of resonance frequency by the ink jet recording apparatus side can be amended, it is correctly detectable that the ink residue decreased to the reference value.

[0139] Drawing 25 shows the operation gestalt of further others of an ink cartridge 180. Ink cartridge 180D shown in drawing 25 (A) equips side-attachment-wall 194b of the ink container 194 with two or more actuators 106. It is desirable to use two or more really fabricated actuators 106 which were shown in drawing 5 as an actuator 106 of these plurality. Two or more actuators 106 set spacing in the vertical direction, and are arranged at side-attachment-wall 194b. By setting two or more actuators 106 in the vertical direction, and arranging spacing for them in it at side-attachment-wall 194b, an ink residue is gradually detectable.

[0140] Ink cartridge 180E shown in drawing 25 (B) equips side-attachment-wall 194b of the ink container 194 with the actuator 606 long in the vertical direction. Change of the ink residue in the ink container 194 is continuously detectable in the vertical direction with the long actuator 606. the die length of an actuator 606 has the die length more than one half of height in side-attachment-wall 194b -- desirable -- drawing 25 (B) -- setting -- an actuator 606 -- side-attachment-wall 194b -- it has the die length to a lower limit mostly from upper limit.

[0141] Like ink cartridge 180D shown in drawing 25 (A), ink cartridge 180F shown in drawing 25 (C) equip side-attachment-wall 194b of the ink container 194 with two or more actuators 106, set predetermined spacing to confrontation of two or more actuators 106, and are equipped with the long breaking-the-water wall 192 in the vertical direction. It is desirable to use two or more really fabricated actuators 106 which were shown in drawing 5 as an actuator 106 of these plurality. The gap filled with ink is formed between an actuator 106 and the breaking-the-water wall 192. Moreover, spacing of the breaking-the-water wall 192 and an actuator 106 is vacated for extent with which ink is not held according to the capillary tube force. When the ink container 194 rolls, the wave of ink occurs in the ink container 194 interior by rolling, a gas and air bubbles will be detected by the impact with an actuator 106, and an actuator 106 may incorrect-operate by it. By establishing the breaking-the-water wall 192 like this invention, ****** of the ink of the actuator 106 neighborhood can be prevented and incorrect actuation of an actuator 106 can be prevented. Moreover, the air bubbles generated because ink rocks the breaking-the-water wall 192 prevent invading into an actuator 106.

[0142] Drawing 26 shows the operation gestalt of further others of an ink cartridge 180. Ink cartridge 180G of drawing 26 (A) have two or more septa 212 caudad prolonged from top-face 194c of the ink container 194. Since predetermined spacing is vacated, the lower limit of each septum 212 and the base of the ink container 194 are opening the pars basilaris ossis occipitalis of the ink container 194 for free passage. Ink cartridge 180G have two or more hold rooms 213 divided as two or more septa 212 be alike, respectively. The pars basilaris ossis occipitalis of two

or more hold rooms 213 is mutually open for free passage. In each of two or more hold rooms 213, top-face 194c of the ink container 194 is equipped with the actuator 106. It is desirable to use the really fabricated actuator 106 which was shown in drawing 5 as an actuator 106 of these plurality. an actuator 106 -- top-face 194c of the hold room 213 of the ink container 194 -- it is mostly arranged in the center. The capacity of the hold room 213 is becoming small gradually as the capacity of the hold room 213 has the largest ink feed hopper 187 side and it keeps away from the ink feed hopper 187 into the ink container 194. Therefore, spacing by which an actuator 106 is arranged is narrow as the ink feed hopper 187 side is large and keeps away from the ink feed hopper 187 into the ink container 194.

[0143] Since ink is discharged from the ink feed hopper 187 and air enters from an air induction inlet 185, ink is consumed at the hold room 213 of the direction in the inner part of ink cartridge 180G from the hold room 213 by the side of the ink feed hopper 187. For example, while the ink of the hold room 213 nearest to the ink feed hopper 187 was consumed and the water level of the ink of the hold room 213 nearest to the ink feed hopper 187 has fallen, ink is filled at other hold rooms 213. If all the ink of the hold room 213 nearest to the ink feed hopper 187 is consumed, air will count from the ink feed hopper 187, and will trespass upon the 2nd hold room 213, the ink in the 2nd hold room 213 will begin to be consumed, and the water level of the ink of the 2nd hold room 213 will begin to fall. It counts from the ink supply room 187, and ink is filled at this time at the hold room 213 of the 3rd henceforth. Thus, ink is consumed in order at the hold room 213 distant from the hold room 213 near the ink feed hopper 187.

[0144] Thus, since an actuator 106 sets spacing to top-face 194c of the ink container 194 and is arranged every hold room 213 at it, as for an actuator 106, reduction of the amount of ink is gradually detectable. Furthermore, since the capacity of the hold room 213 is becoming small gradually into the ink feed hopper 187 to the hold room 213, it can detect frequency highly, so that the time interval to which an actuator 106 detects reduction of the amount of ink becomes small gradually and approaches an ink end.

[0145] Ink cartridge 180H of drawing 26 (B) have one septum 212 caudad prolonged from top-face 194c of the ink container 194. Since predetermined spacing is vacated, the lower limit of a septum 212 and the base of the ink container 194 are opening the pars basilaris ossis occipitalis of the ink container 194 for free passage. Ink cartridge 180H have two hold rooms 213a and 213b divided by the septum 212. The pars basilaris ossis occipitalis of the hold rooms 213a and 213b is mutually open for free passage. The capacity of hold room 213a by the side of the ink feed hopper 187 is seen from the ink feed hopper 187, and is larger than the capacity of hold room 213b in the direction of back. As for the capacity of hold room 213b, it is desirable that it is smaller than the one half of the capacity of hold room 213a.

[0146] Top-face 194c of hold room 213b is equipped with an actuator 106. Furthermore, the buffer 214 which is the slot which catches the air bubbles into which it goes at the time of manufacture of ink cartridge 180H is formed in hold room 213b. In drawing 26 (B), a buffer 214 is formed as a slot which extends in the upper part from side-attachment-wall 194b of the ink container 194. Since the air bubbles which invaded in ink hold room 213b are caught, as for a buffer 214, an actuator 106 can prevent an ink end and the incorrect actuation to detect with air bubbles. Moreover, ink can be consumed to the last by applying the amendment corresponding to the consumption condition of the ink in hold room 213a grasped with the dot counter to the amount of ink after an ink near end is detected until it will be in ink and a condition completely by forming an actuator 106 in top-face 194c of hold room 213b. Furthermore, the amount of ink after ink near end detection which can be consumed is changeable by adjusting the capacity of

hold room 213b by changing the die length and spacing of a septum 212 etc.
[0147] As for drawing 26 (C), hold room 213b of ink cartridge 180I of drawing 26 (B) is filled up with the porosity member 216. The porosity member 216 is installed so that the whole space from the top face in hold room 213b to an inferior surface of tongue may be filled. The porosity member 216 contacts an actuator 106. During the reciprocating motion the time of an ink container falling, and on carriage, air may invade in ink hold room 213b, and this may cause incorrect actuation of an actuator 106. However, if it has the porosity member 216, it can prevent catching air and air going into an actuator 106. Moreover, since the porosity member 216 holds ink, when an ink container shakes, it can prevent applying ink to an actuator 106 and an actuator 106 incorrect-detecting those without ink with those with ink. As for the porosity member 216, it is desirable to install in the hold room 213 where capacity is the smallest. Moreover, by forming an actuator 106 in top-face 194c of nature of hold 213b, amendment can be applied to the amount of ink after an ink near end is detected until it will be in ink and a condition completely, and ink can be consumed to the last. Furthermore, the amount of ink after ink near end detection which can be consumed is changeable by adjusting the capacity of hold room 213b by changing the die length and spacing of a septum 212 etc.
[0148] Drawing 26 (D) shows ink cartridge 180J from which the porosity member 216 of ink cartridge 180I of drawing 26 (C) is constituted by two kinds of porosity members 216A and 216B from which an aperture differs. Porosity member 216A is arranged above porosity member 216B. The aperture of upper porosity member 216A is larger than the aperture of lower porosity member 216B. Or porosity member 216A is formed by the member with low liquid compatibility rather than porosity member 216B. Since the capillary tube force is larger than large porosity member 216A of an aperture, the ink in hold room 213b gathers for lower porous chamber portion material 216B, and the direction of small porosity member 216B of an aperture is held. Therefore, once even an actuator 106 reaches and air detects those without ink, ink will reach an actuator again and it will not detect with those with ink. Furthermore, ****** of about 106-actuator ink becomes good by ink being absorbed by porosity member 216B of a side far from an actuator 106, and the variation of the acoustic-impedance change when detecting ink existence becomes large. Moreover, by forming an actuator 106 in top-face 194c of nature of hold 213b, amendment can be applied to the amount of ink after an ink near end is detected until it will be in ink and a condition completely, and ink can be consumed to the last. Furthermore, the amount of ink after ink near end detection which can be consumed is changeable by adjusting the capacity of hold room 213b by changing the die length and spacing of a septum 212 etc.
[0149] Drawing 27 is the sectional view showing ink cartridge 180K which are other operation gestalten of ink cartridge 180I shown in drawing 26 (C). The porosity member 216 of an ink cartridge 180 shown in drawing 27 is compressed so that the horizontal cross section of the lower part of the porosity member 216 becomes small gradually towards the direction of the base of the ink container 194, and it is designed so that an aperture may become small. In order to compress ink cartridge 180K of drawing 27 (A) so that the aperture in the direction of under the porosity member 216 becomes small, the rib is prepared in the side attachment wall. Since the aperture of the porosity member 216 lower part is small by being compressed, ink is collected in the porosity member 216 lower part, and is held. By ink being absorbed by the porosity member 216 lower part of a side far from an actuator 106, ****** of about 106-actuator ink becomes good, and the variation of the acoustic-impedance change when detecting ink existence becomes large. Therefore, when ink shakes, ink is applied to the actuator 106 with which ink cartridge 180K top face was equipped, it can keep, and an actuator 106 can prevent incorrect-detecting those without

ink with those with ink.
[0150] On the other hand, in order that the horizontal cross section of the lower part of the porosity member 216 may compress ink cartridge 180L of drawing 27 (B) and drawing 27 (C) in the cross direction of the ink container 194 to become small gradually towards the base of the ink container 194, the horizontal cross section of a hold room is becoming small gradually towards the direction of the base of the ink container 194. Since the aperture of the porosity member 216 lower part is small by being compressed, ink is collected in the lower part of the porosity member 216, and is held. By ink being absorbed by the lower part of porosity member 216B of a side far from an actuator 106, ****** of about 106-actuator ink becomes good, and the variation of the acoustic-impedance change when detecting ink existence becomes large. Therefore, when ink shakes, ink is applied to the actuator 106 with which the top face of ink cartridge 180L was equipped, it can keep, and an actuator 106 can prevent incorrect-detecting those without ink with those with ink.
[0151] Drawing 28 shows the operation gestalt of further others of the ink cartridge which used the actuator 106. Ink cartridge 220A of drawing 28 (A) has the 1st septum 222 formed so that it might extend from the top face of ink cartridge 220A to a lower part. Since predetermined spacing is vacated between the lower limit of the 1st septum 222, and the base of ink cartridge 220A, ink can flow into the ink feed hopper 230 through the base of ink cartridge 220A. From the 1st septum 222, the 2nd septum 224 is formed in the ink feed hopper 230 side so that it may extend more nearly up than the base of ink cartridge 220A. Since predetermined spacing is vacated between the upper limit of the 2nd septum 224, and an ink cartridge 220A top face, ink can flow into the ink feed hopper 230 through the top face of ink cartridge 220A.
[0152] By the 1st septum 222, it sees from the ink feed hopper 230, and 1st hold room 225a is formed in the direction in the inner part of the 1st septum 222. On the other hand, by the 2nd septum 224, it sees from the ink feed hopper 230, and 2nd hold room 225b is formed in the near side of the 2nd septum 224. The capacity of 1st hold room 225a is larger than the capacity of 2nd hold room 225b. The capillary tube way 227 is formed by vacating only spacing which can cause capillarity between the 1st septum 222 and the 2nd septum 224. Therefore, the ink of 1st hold room 225a is brought together in the capillary tube way 227 according to the capillary tube force of the capillary tube way 227. Therefore, a gas and air bubbles can prevent mixing to 2nd hold room 225b. Moreover, the water level of the ink in 2nd hold room 225b can descend gradually stably. Since it sees from the ink feed hopper 230 and 1st hold room 225a is formed in the back from 2nd hold room 225b, after the ink of 1st hold room 225a is consumed, the ink of 2nd hold room 225b is consumed.
[0153] The side attachment wall by the side of the ink feed hopper 230 of ink cartridge 220A, i.e., the side attachment wall by the side of the ink feed hopper 230 of 2nd hold room 225b, is equipped with the actuator 106. An actuator 106 detects the consumption condition of the ink in 2nd hold room 225b. By equipping the side attachment wall of 2nd hold room 225b with an actuator 106, when near, an ink residue is stably detectable with an ink end. Furthermore, it can set up freely which time the ink residue in is made into an ink end by changing the height which equips the side attachment wall of 2nd hold room 225b with an actuator 106. Since an actuator 106 is not influenced by the ink by rolling of ink cartridge 220A of rolling when ink is supplied to 2nd hold room 225b by the capillary tube way 227 from 1st hold room 225a, an actuator 106 can measure an ink residue certainly. Furthermore, since the capillary tube way 227 holds ink, ink protects flowing backwards to 1st hold room 225a from 2nd hold room 225b.
[0154] The check valve 228 is formed in the top face of ink cartridge 220A. By the check valve

228, when ink cartridge 220A rolls, it can prevent ink leaking to the ink cartridge 220A exterior. Furthermore, the evaporation from ink cartridge 220A of ink can be prevented by installing a check valve 228 in the top face of ink cartridge 220A. If the ink in ink cartridge 220A is consumed and the negative pressure in ink cartridge 220A exceeds the pressure of a check valve 228, a check valve 228 will open, air will be inhaled to ink cartridge 220A, it will close after that, and the pressure in ink cartridge 220A will be held uniformly.
[0155] Drawing 28 (C) and (D) show the cross section of the detail of a check valve 228. The check valve 228 of drawing 28 (C) has the valve 232 which has wing 232a formed of rubber. The air hole 233 with the exterior of an ink cartridge 220 counters wing 232a, and is prepared in an ink cartridge 220. An air hole 233 is opened and closed by wing 232a. If the ink in an ink cartridge 220 decreases in number and, as for a check valve 228, the negative pressure in an ink cartridge 220 exceeds the pressure of a check valve 228, wing 232a will open inside an ink cartridge 220, and will adopt external air in an ink cartridge 220. The check valve 228 of drawing 28 (D) has the valve 232 and spring 235 which were formed of rubber. If the negative pressure in an ink cartridge 220 exceeds the pressure of a check valve 228, a valve 232 will press and open a spring 235, will inhale external air in an ink cartridge 220, will close a check valve 228 after that, and it will hold the negative pressure in an ink cartridge 220 uniformly.
[0156] Ink cartridge 220B of drawing 28 (B) arranges the porosity member 242 to 1st hold room 225a instead of forming a check valve 228 in ink cartridge 220A of drawing 28 (A). The porosity member 242 prevents ink leaking to the exterior of ink cartridge 220B, when ink cartridge 220B rolls, while holding the ink in ink cartridge 220B.
[0157] As mentioned above, in the carriage and the ink cartridge of another object with which carriage is equipped, although the case where an ink cartridge or carriage was equipped with an actuator 106 was described, it unites with carriage and the ink tank with which an ink jet recording apparatus is equipped with carriage may be equipped with an actuator 106. Furthermore, the ink tank of the off-carriage method which supplies ink to carriage may be equipped with an actuator 106 through the tube of carriage and another object etc. Furthermore, the ink cartridge which the recording head and the ink container were united and was constituted exchangeable may be equipped with the actuator of this invention.
[0158] As mentioned above, although this invention was explained using the gestalt of operation, the technical range of this invention is not limited to the range given in the gestalt of the above-mentioned implementation. Various modification or amelioration can be added to the gestalt of the above-mentioned implementation. It is clear from the publication of a claim that the gestalt's which added such modification or amelioration it may be contained in the technical range of this invention.

## DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]
[Drawing 1] It is drawing showing the detail of an actuator 106.
[Drawing 2] It is drawing showing the circumference of an actuator 106, and its equal circuit.
[Drawing 3] It is drawing showing the relation between the consistency of ink, and the resonance frequency of the ink detected by the actuator 106.
[Drawing 4] It is drawing showing the back EMF wave of an actuator 106.
[Drawing 5] It is drawing showing other operation gestalten of an actuator 106.

[Drawing 6] It is drawing showing some cross sections of the actuator 106 shown in drawing 5 .
[Drawing 7] It is drawing showing the cross section of the whole actuator 106 shown in drawing 6 .
[Drawing 8] It is drawing showing the manufacture approach of the actuator 106 shown in drawing 5 .
[Drawing 9] It is drawing showing the operation gestalt of further others of the ink cartridge of this invention.
[Drawing 10] It is drawing showing other operation gestalten of through tube 1c.
[Drawing 11] It is drawing showing other operation gestalten of an actuator 660.
[Drawing 12] It is drawing showing the operation gestalt of further others of an actuator 670.
[Drawing 13] It is the perspective view showing the module object 100.
[Drawing 14] It is the exploded view showing the configuration of the module object 100 shown in drawing 13 .
[Drawing 15] It is drawing showing other operation gestalten of the module object 100.
[Drawing 16] It is the exploded view showing the configuration of the module object 100 shown in drawing 15 .
[Drawing 17] It is drawing showing the operation gestalt of further others of the module object 100.
[Drawing 18] It is drawing showing the example of the cross section which equipped the ink container 1 with the module object 100 shown in drawing 13 .
[Drawing 19] It is drawing showing the operation gestalt of further others of the module object 100.
[Drawing 20] It is drawing showing the operation gestalt of further others of the module object 100.
[Drawing 21] It is drawing showing the operation gestalt of the ink cartridge and ink jet recording device using the actuator 106 shown in drawing 1 and drawing 2 .
[Drawing 22] It is drawing showing the detail of an ink jet recording device.
[Drawing 23] It is drawing showing other operation gestalten of an ink cartridge 180 shown in drawing 22 .
[Drawing 24] It is drawing showing the operation gestalt of further others of an ink cartridge 180.
[Drawing 25] It is drawing showing the operation gestalt of further others of an ink cartridge 180.
[Drawing 26] It is drawing showing the operation gestalt of further others of an ink cartridge 180.
[Drawing 27] It is drawing showing other operation gestalten of an ink cartridge 180 shown in drawing 26 (C).
[Drawing 28] It is drawing showing the operation gestalt of further others of the ink cartridge using the module object 100.
[Description of Notations]
1 ... Container
1a ... Base
1b ... Side attachment wall
1c, 940a ... Through tube
1d and ... a side face
1e, 1f ... Level difference section

1g, 1h ... Slot
2 ... Ink feed hopper
67 ... Plate
68 ... Float
71 ... Adhesives layer
78 80,178 ... Substrate
73, 82, a piezo-electric diaphragm
74 75 ... Ink absorber
76 ... Packing
77 ... Caulking hole
81 ... Crevice
100,400 500,700 ... Module object
101, 401, 501 ... Liquid-container attachment section
102 ... Pedestal
104 362 ... Reed wire
105, 405, 505 ... Piezoelectric device applied part
106, 650, 660, 670 ... Actuator
108 ... Film
110 ... Plate
112, 412, 370 ... Through tube
113 ... Crevice
114 ... Opening
116 ... Cylinder section
160 ... Piezo-electric layer
162 ... Cavity
164 ... Up electrode
166 ... Lower electrode
168 ... Up electrode terminal
170 ... Lower electrode terminal
172 ... Auxiliary electrode
174 ... Piezoelectric device
176 ... Diaphragm
180 ... Ink cartridge
181 ... Air supply opening
182 ... Ink induction
183 ... Ink inlet
184 ... Electrode holder
185 ... Air induction inlet
186 ... Head plate
187 ... Ink feed hopper
188 ... Nozzle plate
190 ... Nozzle
192 ... Breaking-the-water wall
194 ... Ink container
194a ... Base
194b ... Side attachment wall

194c ... Top face
212 ... Septum
213, 213a, 213b ... Hold room
214 ... Buffer
216, 216a, 216b ... Porosity member
220 ... Ink cartridge
222 ... The 1st septum
224 ... The 2nd septum
225a ... 1st hold room
225b ... 2nd hold room
227 ... Capillary tube way
228 ... Check valve
230 ... Ink feed hopper
232 ... Valve
232a ... Wing
233 ... Air hole
235 ... Spring
242 ... Porosity member
250 ... Carriage
252 ... Recording head
254 ... Ink supply needle
256 ... Subtank unit
258 258' ... Heights
260 260' ... Elastic wave generating means
262 ... Ink room
266 ... Film valve
270 ... Valve element
272 ... Ink cartridge
274 ... Container
274a ... Base
274b ... Side face
276 ... Ink feed hopper
278 ... Crevice
280 280' ... Gelation material
282 ... Packing
284 ... Spring
286 ... Valve element
288 ... Semi-conductor storage means
290 ... Container
290a ... Base
292, 294, 296 ... Ink room
298, 300, 302 ... Ink feed hopper
304, 306, 308 ... Gelation material
310, 312, 314 ... Crevice
316 ... Plate
318 ... Float

350 ... Attachment plate
360 ... Liquid-container attachment section
364 ... Mold section
372 ... Sealing structure
402 502 ... Pedestal
403 503 ... Cylinder section
404 504 ... Reed wire
408 508 ... Film
410 510 ... Plate
413 513 ... Crevice
414 514 ... Opening
600 ... Mold structure
606 ... Actuator
610 ... Circuit board
612 ... Terminal
940 941 ... Green sheet
942 944 ... Conductive layer
944' ... Connection
947 948 ... Spacing member
delta h1, delta h2 ... Change of an oil level
K ... Ink

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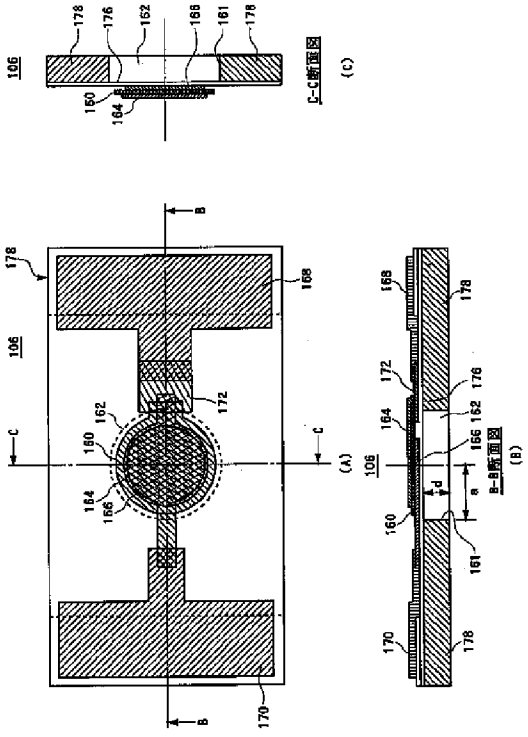
(54)【発明の名称】　圧電装置、モジュール体、及び液体容器

(57)【要約】
【課題】　検出電極取付けに起因する複雑なシール構造を要することなく、インク残量を正確に検出すること。
【解決手段】　液体容器に装着され、液体容器内の液体の消費状態を検知する圧電装置であって、圧電装置において振動する振動部は、一方の面が液体容器内の液体と接触する振動板、振動板の他方の面に形成された下部電極、下部電極上に形成された圧電層、及び圧電層上に形成された上部電極を備え、振動部は、圧電層は下部電極を被覆するよう形成されるとともに、上部電極は、下部電極を被覆し、圧電層は上部電極よりもはみ出す圧電装置。



【特許請求の範囲】
【請求項１】　液体容器に装着され、該液体容器内の液体の消費状態を検知する圧電装置であって、
前記圧電装置において振動する振動部は、
一方の面が液体容器内の液体と接触する振動板と、
該振動板の他方の面に形成された下部電極と、
該下部電極上に形成された圧電層と、
該圧電層上に形成された上部電極とを備え、
前記振動部は、前記圧電層が前記下部電極を被覆するよう形成されるとともに、前記上部電極は下部電極を被覆し、圧電層は上部電極よりもはみ出すことを特徴とする圧電装置。
【請求項２】　前記圧電装置は、
上面が前記振動板の液体と接触する下面側と接し、下面が前記液体容器内の液体と接触する基板を更に備え、前記基板が、前記振動板の振動部に対応する位置に液体と接触する空洞を有することを特徴とする請求項１に記載の圧電装置。
【請求項３】　前記空洞の面積は前記下部電極の面積よりも大きいことを特徴とする請求項２に記載の圧電装置。
【請求項４】　前記残留振動による前記振動板の変形は、前記基板の変形よりも大きいことを特徴とする請求項１に記載の圧電装置。
【請求項５】　前記圧電層の圧電効果を発生する部分の面積は、前記下部電極の面積とほぼ同じであることを特徴とする請求項１に記載の圧電装置。
【請求項６】　前記上部電極、前記圧電層、及び前記下部電極の主要部が、矩形であることを特徴とする請求項１に記載の圧電装置。
【請求項７】　前記上部電極、前記圧電層、及び前記下部電極の主要部が、ほぼ円形であることを特徴とする請求項１に記載の圧電装置。
【請求項８】　前記空洞がほぼ円形であり、前記空洞の半径を前記空洞の深さで割った値が、３π／８より大きいことを特徴とする請求項３に記載の圧電装置。
【請求項９】　前記圧電装置が、前記振動部近傍の音響インピーダンスの変化を検知することにより前記液体容器内の液体の消費状態を検知することを特徴とする請求項１に記載の圧電装置。
【請求項１０】　前記圧電装置が、前記振動部に残留する残留振動によって発生する逆起電力に基づいて前記音響インピーダンスの変化を検知して、前記液体容器内の液体の消費状態を検知することを特徴とする請求項９に記載の圧電装置。
【請求項１１】　請求項１乃至１０記載の圧電装置が装着されたことを特徴とする液体容器。
【請求項１２】　前記圧電装置は、液体容器の壁面に形成された通孔又は凹部内に設けられていることを特徴とする請求項１１に記載の液体容器。
【請求項１３】　液体容器に装着され、前記液体容器内の液体の消費状態を検知するためのモジュール体であって、
前記モジュール体は、残留振動によって発生する逆起電力に基づいて前記液体の消費状態を検知する圧電装置と、
前記圧電装置を前記液体容器に取付けるための、前記圧電装置と一体化された取付構造体とを備え、
前記圧電装置は、
一方の面が液体容器内の液体と接触する振動板、
該振動板の他方の面に形成された下部電極該下部電極上に形成された圧電層、及び該圧電層の上に設けられた上部電極を備え、
前記圧電層は、前記下部電極を被覆するよう形成されるとともに、前記上部電極は下部電極を被覆し、圧電層は上部電極よりはみ出していることを特徴とするモジュール体。
【請求項１４】　前記取付構造体は、
上面が前記振動板の液体と接触する下面側と面し、下面が前記液体容器内の液体と接触する取付部材を有し、
前記取付部材が、前記振動板の振動部分の位置に液体と接触する空洞を有することを特徴とする請求項１３に記載のモジュール体。
【請求項１５】　前記空洞の面積が、前記下部電極の面積よりも大きいことを特徴とする請求項１４記載のモジュール体。
【請求項１６】　前記空洞がほぼ円形であり、前記空洞の半径を、前記空洞の深さで割った値が、３π／８より大きいことを特徴とする請求項１３に記載のモジュール体。
【請求項１７】　前記モジュール体の前記取付構造体が、中心に開口部を含み、前記開口部に前記圧電装置が配設されたことを特徴とする請求項１３に記載のモジュール体。
【請求項１８】　前記開口部の面積は、前記圧電層の圧電効果を発生する部分の面積よりも大きいことを特徴とする請求項１３に記載のモジュール体。
【請求項１９】　前記圧電装置は、前記取付構造体に対し着脱可能であることを特徴とする請求項１３に記載のモジュール体。
【請求項２０】　請求項１３乃至１９に記載のモジュール体が配置されたことを特徴とする液体容器。
【発明の詳細な説明】
【０００１】
【発明の属する技術分野】本発明は、音響インピーダンスの変化を検出することで、その中でも特に共振周波数の変化を検出することでインク等の液体を収容する液体容器内の液体の消費状態を検知するための圧電装置（アクチュエータ）が備えられた液体容器に関する。さらに詳しくは、圧力発生手段により圧力発生室のインクを印

刷データに対応させて加圧し、ノズル開口からインク滴を吐出させて印刷するインクジェット記録装置に適した圧電装置、モジュール体、及び液体容器に関するものである。

【０００２】

【従来の技術】インクジェット記録装置は、圧力発生室を加圧する圧力発生手段と、加圧されたインクをノズル開口からインク滴として吐出するノズル開口とを備えたインクジェット記録ヘッドをキャリッジに搭載する。インクジェット記録装置は、インクタンクのインクを流路を介して記録ヘッドに供給しながら印刷を継続可能に構成されている。インクタンクは、インクが消費された時点で、ユーザが簡単に交換できるように着脱可能なカートリッジとして構成されている。

【０００３】従来、インクカートリッジのインク消費の管理方法として、記録ヘッドでのインク滴の吐出数やメンテナンスにより吸引されたインク量をソフトウエアにより積算してインク消費を計算により管理する方法と、インクカートリッジに液面検出用の電極を取付けることにより、実際にインクが所定量消費された時点を管理する方法などがある。

【０００４】しかしながら、ソフトウェアによりインク滴の吐出数やインク量を積算してインク消費を計算上管理する方法は、ユーザサイドでの印刷形態等により誤差が生じたり、また同一カートリッジの再装着時には大きな誤差が生じるという問題がある。また、使用環境により、例えば室温が極端な高低、あるいはインクカートリッジの開封後の経過時間などによってインクカートリッジ内の圧力やインクの粘度が変化して、計算上のインク消費量と実際の消費量との間に無視できない誤差が生じてしまうという問題もあった。一方、電極によりインクが消費された時点を管理する方法は、インクの実量を検出できるため、インク残量を高い信頼性で管理できる。しかしながら、インクの液面の検出をインクの導電性に頼るので、検出可能なインクの種類が限定されたり、また電極のシール構造が複雑化する問題がある。また、電極の材料として通常は導電性が良く耐腐食性も高い貴金属を使用するので、インクカートリッジの製造コストがかさむという問題もあった。さらに、２本の電極を装着する必要があるため、製造工程が多くなり結果として製造コストがかさんでしまうという問題もあった。

【０００５】

【発明が解決しようとする課題】本発明は、共振周波数からインピーダンスの変化を検出することで液体を収容する液体容器内の液体の消費状態を検知するための圧電装置が備えられた液体容器に関し、さらに詳しくは、圧力発生手段により圧力発生室のインクを印刷データに対応させて加圧してノズル開口からインク滴を吐出させて印刷するインクジェット記録装置に適用されるインクカートリッジに備えられ、インクカートリッジ内のインクの消費状態を検出する圧電装置及びモジュール体に関するものである。

【０００６】

【課題を解決するための手段】即ち、本発明の第１の形態における圧電装置は、液体容器に装着され、該液体容器内の液体の消費状態を検知する圧電装置であって、圧電装置において振動する振動部は、一方の面が液体容器内の液体と接触する振動板と、該振動板の他方の面に形成された下部電極と、該下部電極上に形成された圧電層と、及び該圧電層上に形成された上部電極とを備え、振動部は、圧電層が下部電極を被覆するよう形成されるとともに、上部電極が下部電極を被覆し、圧電層が上部電極よりもはみ出していることが好ましい。

【０００７】また、圧電装置は、上面が振動板の液体と接触する下面側と接し、下面が液体容器内の液体と接触する基板を更に備え、基板が、振動板の振動部分の位置に液体と接触する空洞を有することが好ましい。更に、空洞の面積が下部電極の面積よりも大きいことが好ましい。残留振動による振動板の変形は、基板の変形よりも大きいことが好ましい。圧電層の圧電効果を発生する部分の面積は、下部電極の面積とほぼ同じであってもよい。また、上部電極、圧電層、及び下部電極の主要部が、矩形であることが好ましい。上部電極、圧電層、及び下部電極の主要部は、ほぼ円形であってもよい。空洞がほぼ円形であり、空洞の半径を空洞の深さで割った値が、３π／８より大きいことが好ましい。圧電装置が、振動部近傍の音響インピーダンスの変化を検知することにより液体容器内の液体の消費状態を検知することが好ましい。また、圧電装置が、圧電層の発振によって生じる残留振動によって逆起電力を発生させることによって、音響インピーダンスの変化を検知して液体容器内の液体の消費状態を検知することが好ましい。また、上記の圧電装置が装着される液体容器であることが好ましい。更に、圧電装置は、液体容器の壁面に形成された通孔又は凹部内に設けられていることが好ましい。

【０００８】本発明の第２の形態におけるモジュール体は、液体容器に装着され、液体容器内の液体の消費状態を検知するためのモジュール体であって、モジュール体は、発振後に残留する残留振動によって逆起電力を発生することで液体の消費状態を検知する圧電装置と、圧電装置を液体容器に取付けるための、圧電装置と一体化された取付構造体とを備え、圧電装置は、一方の面が液体容器内の液体と接触する振動板、該振動板の他方の面に形成された下部電極、該下部電極上に形成された圧電層、及び該圧電層の上に設けられた上部電極を備え、圧電層は下部電極を被覆するよう形成されるとともに、上部電極は下部電極を被覆し、圧電層は上部電極よりもはみ出していることが好ましい。

【０００９】更に、取付構造体は、上面が振動板の液体と接触する下面側と面し、下面が液体容器内の液体と接

触する取付部材を有し、取付部材が、振動板の振動部分の位置に液体と接触する空洞を有することが好ましい。更に、空洞の面積は、下部電極の面積よりも大きいことが好ましい。空洞がほぼ円形であり、空洞の半径を、空洞の深さで割った値が、３π／８より大きいことが好ましい。モジュール体の取付構造体が、中心に開口部を含み、開口部に圧電装置が配設されてもよい。更に、開口部の面積は、圧電層の圧電効果を発生する部分の面積よりも大きいことが好ましい。また、圧電装置は、取付構造体に対し着脱可能であってもよい。更に、上記のモジュール体が配置された液体容器であることが好ましい。

【００１０】なお上記の発明の概要は、本発明の必要な特徴の全てを列挙したものではなく、これらの特徴群のサブコンビネーションも又発明となりうる。

【００１１】

【発明の実施の形態】以下、発明の実施の形態を通じて本発明を説明するが、以下の実施形態はクレームにかかる発明を限定するものではなく、又実施形態の中で説明されている特徴の組み合わせの全てが発明の解決手段に必須であるとは限らない。

【００１２】本発明の基本的概念は、振動現象を利用することで、液体容器内の液体の状態（液体容器内の液体の有無、液体の量、液体の水位、液体の種類、液体の組成を含む）を検出することである。具体的な振動現象を利用した液体容器内の液体の状態の検出としてはいくつかの方法が考えられる。例えば弾性波発生手段が液体容器の内部に対して弾性波を発生し、液面あるいは対向する壁によって反射する反射波を受波することで、液体容器内の媒体およびその状態の変化を検出する方法がある。また、これとは別に、振動する物体の振動特性から音響インピーダンスの変化を検知する方法もある。音響インピーダンスの変化を利用する方法としては、圧電素子を有する圧電装置またはアクチュエータの振動部を振動させ、その後に振動部に残留する残留振動によって生ずる逆起電力を測定することによって、共振周波数または逆起電力波形の振幅を検出することで音響インピーダンスの変化を検知する方法や、測定機、例えば伝送回路等のインピーダンスアナライザによって液体のインピーダンス特性またはアドミッタンス特性を測定し、電流値や電圧値の変化または、振動を液体に与えたときの電流値や電圧値の周波数による変化を測定する方法がある。以下、圧電装置またはアクチュエータの動作原理の詳細について説明する。

【００１３】図１および図２は、圧電装置の一実施形態であるアクチュエータ１０６の詳細および等価回路を示す。ここでいうアクチュエータは、少なくとも音響インピーダンスの変化を検知して液体容器内の液体の消費状態を検出する方法に用いられる。特に、残留振動により共振周波数の検出することで、少なくとも音響インピーダンスの変化を検知して液体容器内の液体の消費状態を検出する方法に用いられる。図１（Ａ）は、アクチュエータ１０６の拡大平面図である。図１（Ｂ）は、アクチュエータ１０６のＢ－Ｂ断面を示す。図１（Ｃ）は、アクチュエータ１０６のC-C断面を示す。さらに図２（A)および図２（B)は、アクチュエータ１０６の等価回路を示す。また、図２（C)および図２（D)は、それぞれインクカートリッジ内にインクが満たされているときのアクチュエータ１０６を含む周辺およびその等価回路を示し、図２（E)および図２（F)は、それぞれインクカートリッジ内にインクが無いときのアクチュエータ１０６を含む周辺およびその等価回路を示す。

【００１４】アクチュエータ１０６は、ほぼ中央に円形状の開口１６１を有する基板１７８と、開口１６１を被覆するように基板１７８の一方の面（以下、表面という）に配備される振動板１７６と、振動板１７６の表面の側に配置される圧電層１６０と、圧電層１６０を両方からはさみこむ上部電極１６４および下部電極１６６と、上部電極１６４と電気的に結合する上部電極端子１６８と、下部電極１６６と電気的に結合する下部電極端子１７０と、上部電極１６４および上部電極端子１６８の間に配設され、かつ両者を電気的に結合する補助電極１７２と、を有する。圧電層１６０、上部電極１６４および下部電極１６６はそれぞれの主要部として円形部分を有する。圧電層１６０、上部電極１６４および下部電極１６６のそれぞれの円形部分は圧電素子を形成する。

【００１５】振動板１７６は、基板１７８の表面に、開口１６１を覆うように形成される。キャビティ１６２は、振動板１７６の開口１６１と面する部分と基板１７８の表面の開口１６１とによって形成される。基板１７８の圧電素子とは反対側の面（以下、裏面という）は液体容器側に面しており、キャビティ１６２は液体と接触するように構成されている。キャビティ１６２内に液体が入っても基板１７８の表面側に液体が漏れないように、振動板１７６は基板１７８に対して液密に取り付けられる。

【００１６】下部電極１６６は振動板１７６の表面、即ち液体容器とは反対側の面に位置しており、下部電極１６６の主要部である円形部分の中心と開口１６１の中心とがほぼ一致するように取り付けられている。なお、下部電極１６６の円形部分の面積が開口１６１の面積よりも小さくなるように設定されている。一方、下部電極１６６の表面側には、圧電層１６０が、その円形部分の中心と開口１６１の中心とがほぼ一致するように形成されている。圧電層１６０の円形部分の面積は、開口１６１の面積よりも小さく、かつ下部電極１６６の円形部分の面積よりも大きくなるように設定されている。

【００１７】一方、圧電層１６０の表面側には、上部電極１６４が、その主要部である円形部分の中心と開口１６１の中心とがほぼ一致するように形成される。上部電極１６４の円形部分の面積は、開口１６１および圧電層

１６０の円形部分の面積よりも小さく、かつ下部電極１６６の円形部分の面積よりも大きくなるよう設定されている。

【００１８】したがって、圧電層１６０の主要部は、上部電極１６４の主要部と下部電極１６６の主要部とによって、それぞれ表面側と裏面側とから挟みこまれる構造となっていて、圧電層１６０を効果的に変形駆動することができる。圧電層１６０、上部電極１６４および下部電極１６６のそれぞれの主要部である円形部分がアクチュエータ１０６における圧電素子を形成する。上述のように圧電素子は振動板１７６に接している。また、上部電極１６４の円形部分、圧電層１６０の円形部分、下部電極１６６の円形部分および開口１６１のうちで、面積が最も大きいのは開口１６１である。この構造によって、振動板１７６のうち実際に振動する振動領域は、開口１６１によって決定される。また、上部電極１６４の円形部分、圧電層１６０の円形部分および下部電極１６６の円形部分は開口１６１より面積が小さいので、振動板１７６がより振動しやすくなる。さらに、圧電層１６０と電気的に接続する下部電極１６６の円形部分および上部電極１６４の円形部分のうち、下部電極１６６の円形部分の方が小さい。従って、下部端子１６６の円形部分が圧電層１６０のうち圧電効果を発生する部分を決定する。

【００１９】したがって、圧電層１６０の主要部は、上部電極１６４の主要部と下部電極１６６の主要部とによって、それぞれ表面側と裏面側とから挟みこまれる構造となっていて、圧電層１６０を効果的に変形駆動することができる。圧電層１６０、上部電極１６４および下部電極１６６のそれぞれの主要部である円形部分がアクチュエータ１０６における圧電素子を形成する。上述のように圧電素子は振動板１７６に接している。また、上部電極１６４の円形部分、圧電層１６０の円形部分、下部電極１６６の円形部分および開口１６１のうちで、面積が最も大きいのは開口１６１である。この構造によって、振動板１７６のうち実際に振動する振動領域は、開口１６１によって決定される。また、上部電極１６４の円形部分、圧電層１６０の円形部分および下部電極１６６の円形部分は開口１６１より面積が小さいので、振動板１７６がより振動しやすくなる。さらに、圧電層１６０と電気的に接続する下部電極１６６の円形部分および上部電極１６４の円形部分のうち、下部電極１６６の円形部分の方が小さい。従って、下部端子１６６の円形部分が圧電層１６０のうち圧電効果を発生する部分を決定する。

【００２０】圧電素子を形成する圧電層１６０、上部電極１６４、及び下部電極１６６の円形部分は、その中心が、開口部１６１の中心とほぼ一致する。また、振動板１７６の振動部分を決定する円形状の開口部１６１の中心は、アクチュエータ１０６のほぼ中心に設けられている。したがって、アクチュエータ１０６の振動部の中心は、アクチュエータの中心とほぼ一致する。更に、圧電素子の主部及び、振動板１７６の振動部分が、円形な形状を有するので、アクチュエータ１０６の振動部は、アクチュエータ１０６の中心に対して対称な形状である。

【００２１】振動部が、アクチュエータ１０６の中心に対して対称な形状であるので、構造の非対称性から生じる不要な振動を励起しないようにすることができる。そのため、共振周波数の検出精度が向上する。更に、振動部が、アクチュエータ中心に対して対称な形状であるので、製造しやすく、圧電素子ごとの形状のばらつきを小さくできる。したがって、圧電素子ごとの共振周波数のばらつきが小さくなる。また、振動部が、等方的な形状であるので、接着の際、固定のばらつきの影響を受けにくい。液体容器に均等に接着される。したがって、アクチュエータ１０６の液体容器への実装性がよい。

【００２２】更に、振動板１７６の振動部分が、円形な形状を有するので、圧電層１６０の残留振動の共振モードにおいて、低次、例えば一次の共振モードが支配的となり、単一のピークが出現する。そのため、ピークとノイズとを、明確に区別することができるので、共振周波数を明確に検出することができる。また、円形な形状の振動板１７６の振動部分の面積を大きくすることによって、逆起電力波形の振幅及び液体の有無による共振周波数の振幅の差が大きくなり、共振周波数の検出の精度を更に向上できる。

【００２３】振動板１７６の振動による変位は、基板１７８の振動による変位よりもはるかに大きい。アクチュエータ１０６は、コンプライアンスの小さい、すなわち振動によって変位しにくい基板１７８と、コンプライアンスの大きい、すなわち振動によって変位しやすい振動板１７６との２層構造を有する。この２層構造によって、基板１７８によって液体容器に確実に固定されながら、かつ振動による振動板１７６の変位を大きくできるので、逆起電力波形の振幅及び液体の有無による共振周波数の振幅の差が大きくなり、共振周波数の検出の精度が向上できる。更に、振動板１７６のコンプライアンスが大きいので、振動の減衰が小さくなり、共振周波数の検出の精度が向上できる。また、アクチュエータ１０６の振動の節は、キャビティ１６２の外周部、すなわち開口部１６１の縁付近に位置する。

【００２４】上部電極端子１６８は、補助電極１７２を介して上部電極１６４と電気的に接続するように振動板１７６の表面側に形成される。一方、下部電極端子１７０は、下部電極１６６に電気的に接続するように振動板１７６の表面側に形成される。上部電極１６４は、圧電層１６０の表面側に形成されるため、上部電極端子１６８と接続する途中において、圧電層１６０の厚さと下部電極１６６の厚さとの和に等しい段差を有する必要がある。上部電極１６４だけでこの段差を形成することは難

しく、かりに可能であったとしても上部電極１６４と上部電極端子１６８との接続状態が弱くなってしまい、切断してしまう危険がある。そこで、補助電極１７２を補助部材として用いて上部電極１６４と上部電極端子１６８とを接続させている。このようにすることで、圧電層１６０も上部電極１６４も補助電極１７２に支持された構造となり、所望の機械的強度を得ることができ、また上部電極１６４と上部電極端子１６８との接続を確実にすることが可能となる。

【００２５】なお、圧電素子と振動板１７６のうちの圧電素子に直面する振動領域とが、アクチュエータ１０６において実際に振動する振動部である。また、アクチュエータ１０６に含まれる部材は、互いに焼成されることによって一体的に形成されることが好ましい。アクチュエータ１０６を一体的に形成することによって、アクチュエータ１０６の取り扱いが容易になる。さらに、基板１７８の強度を高めることによって振動特性が向上する。即ち、基板１７８の強度を高めることによって、アクチュエータ１０６の振動部のみが振動し、アクチュエータ１０６のうち振動部以外の部分が振動しない。また、アクチュエータ１０６の振動部以外の部分が振動しないためには、基板１７８の強度を高めるのに対し、アクチュエータ１０６の圧電素子を薄くかつ小さくし、振動板１７６を薄くすることによって達成できる。

【００２６】圧電層１６０の材料としては、ジルコン酸チタン酸鉛（ＰＺＴ）、ジルコン酸チタン酸鉛ランタン（ＰＬＺＴ）または鉛を使用しない鉛レス圧電膜を用いることが好ましく、基板１７８の材料としてジルコニアまたはアルミナを用いることが好ましい。また、振動板１７６には、基板１７８と同じ材料を用いることが好ましい。上部電極１６４、下部電極１６６、上部電極端子１６８および下部電極端子１７０は、導電性を有する材料、例えば、金、銀、銅、プラチナ、アルミニウム、ニッケルなどの金属を用いることができる。

【００２７】上述したように構成されるアクチュエータ１０６は、液体を収容する容器に適用することができる。例えば、インクジェット記録装置に用いられるインクカートリッジやインクタンク、あるいは記録ヘッドを洗浄するための洗浄液を収容した容器などに装着することができる。

【００２８】図１および図２に示されるアクチュエータ１０６は、液体容器の所定の場所に、キャビティ１６２を液体容器内に収容される液体と接触するように装着される。液体容器に液体が十分に収容されている場合には、キャビティ１６２内およびその外側は液体によって満たされている。一方、液体容器の液体が消費され、アクチュエータの装着位置以下まで液面が降下すると、キャビティ１６２内には液体は存在しないか、あるいはキャビティ１６２内にのみ液体が残存されその外側には気体が存在する状態となる。アクチュエータ１０６は、この状態の変化に起因する、少なくとも音響インピーダンスの相違を検出する。それによって、アクチュエータ１０６は、液体容器に液体が十分に収容されている状態であるか、あるいはある一定以上の液体が消費された状態であるかを検知することができる。さらに、アクチュエータ１０６は、液体容器内の液体の種類も検出することが可能である。

【００２９】ここでアクチュエータによる液面検出の原理について説明する。

【００３０】媒体の音響インピーダンスの変化を検出するには、媒体のインピーダンス特性またはアドミッタンス特性を測定する。インピーダンス特性またはアドミッタンス特性を測定する場合には、例えば伝送回路を利用することができる。伝送回路は、媒体に一定電圧を印加し、周波数を変えて媒体に流れる電流を測定する。または、伝送回路は、媒体に一定電流を供給し、周波数を変えて媒体に印加される電圧を測定する。伝送回路で測定された電流値または電圧値の変化は音響インピーダンスの変化を示す。また、電流値または電圧値が極大または極小となる周波数ｆｍの変化も音響インピーダンスの変化を示す。

【００３１】上記の方法とは別に、アクチュエータは、液体の音響インピーダンスの変化を共振周波数のみの変化を用いて検出することができる。液体の音響インピーダンスの変化を利用する方法として、アクチュエータの振動部が振動した後に振動部に残留する残留振動によって生ずる逆起電力を測定することによって共振周波数を検出する方法を用いる場合には、例えば圧電素子を利用することができる。圧電素子は、アクチュエータの振動部に残留する残留振動により逆起電力を発生する素子であり、アクチュエータの振動部の振幅によって逆起電力の大きさが変化する。従って、アクチュエータの振動部の振幅が大きいほど検出がしやすい。また、アクチュエータの振動部における残留振動の周波数によって逆起電力の大きさが変化する周期が変わる。従って、アクチュエータの振動部の周波数は逆起電力の周波数に対応する。ここで、共振周波数は、アクチュエータの振動部と振動部に接する媒体との共振状態における周波数をいう。

【００３２】共振周波数ｆｓを得るために、振動部と媒体とが共振状態であるときの逆起電力測定によって得られた波形をフーリエ変換する。アクチュエータの振動は、一方向だけの変形ではなく、たわみや伸長等様々な変形をともなうので、共振周波数ｆｓを含め様々な周波数を有する。よって、圧電素子と媒体とが共振状態であるときの逆起電力の波形をフーリエ変換し、最も支配的な周波数成分を特定することで、共振周波数ｆｓを判断する。

【００３３】周波数ｆｍは、媒体のアドミッタンスが極大またはインピーダンスが極小であるときの周波数であ

る。共振周波数ｆｓとすると、周波数ｆｍは、媒体の誘電損失または機械的損失などによって、共振周波数ｆｓに対しわずかな誤差を生ずる。しかし、実測される周波数ｆｍから共振周波数ｆｓを導出することは手間がかかるため、一般には、周波数ｆｍを共振周波数に代えて使用する。ここで、アクチュエータ１０６の出力を伝送回路に入力することで、アクチュエータ１０６は少なくとも音響インピーダンスを検出することができる。

【００３４】媒体のインピーダンス特性またはアドミッタンス特性を測定し周波数ｆｍを測定する方法と、アクチュエータの振動部における残留振動振動によって生ずる逆起電力を測定することによって共振周波数ｆｓを測定する方法と、によって特定される共振周波数に差がほとんど無いことが実験によって証明されている。

【００３５】アクチュエータ１０６の振動領域は、振動板１７６のうち開口１６１によって決定されるキャビティ１６２を構成する部分である。液体容器内に液体が充分に収容されている場合には、キャビティ１６２内には、液体が満たされ、振動領域は液体容器内の液体と接触する。一方で、液体容器内に液体が充分にない場合には、振動領域は液体容器内のキャビティに残った液体と接するか、あるいは液体と接触せず、気体または真空と接触する。

【００３６】本発明のアクチュエータ１０６にはキャビティ１６２が設けられ、それによって、アクチュエータ１０６の振動領域に液体容器内の液体が残るように設計できる。その理由は次の通りである。

【００３７】アクチュエータの液体容器への取り付け位置や取り付け角度によっては、液体容器内の液体の液面がアクチュエータの装着位置よりも下方にあるにもかかわらず、アクチュエータの振動領域に液体が付着してしまう場合がある。振動領域における液体の有無だけでアクチュエータが液体の有無を検出している場合には、アクチュエータの振動領域に付着した液体が液体の有無の正確な検出を妨げる。たとえば、液面がアクチュエータの装着位置よりも下方にある状態のとき、キャリッジの往復移動などにより液体容器が揺動して液体が波うち、振動領域に液滴が付着してしまうと、アクチュエータは液体容器内に液体が充分にあるとの誤った判断をしてしまう。そこで、逆にそこに液体を残存した場合であっても液体の有無を正確に検出するように設計されたキャビティを積極的に設けることで、液体容器が揺動して液面が波立ったとしても、アクチュエータの誤動作を防止することができる。このように、キャビティを有するアクチュエータを用いることで、誤動作を防ぐことができる。

【００３８】また、図２（Ｅ)に示すように、液体容器内に液体が無く、アクチュエータ１０６のキャビティ１６２に液体容器内の液体が残っている場合を、液体の有無の閾値とする。すなわち、キャビティ１６２の周辺に液体が無く、この閾値よりキャビティ内の液体が少ない場合は、インク無しと判断し、キャビティ１６２の周辺に液体が有り、この閾値より液体が多い場合は、インク有りと判断する。例えば、アクチュエータ１０６を液体容器の側壁に装着した場合、液体容器内の液体がアクチュエータの装着位置よりも下にある場合をインク無しと判断し、液体容器内の液体がアクチュエータの装着位置より上にある場合をインク有りと判断する。このように閾値を設定することによって、キャビティ内のインクが乾燥してインクが無くなったときであってもインク無しと判断し、キャビティ内のインクが無くなったところにキャリッジの揺れなどで再度インクがキャビティに付着しても閾値を越えないので、インク無しと判断することができる。

【００３９】ここで、図１および図２を参照しながら逆起電力の測定による媒体とアクチュエータ１０６の振動部との共振周波数から液体容器内の液体の状態を検出する動作および原理について説明する。アクチュエータ１０６において、上部電極端子１６８および下部電極端子１７０を介して、それぞれ上部電極１６４および下部電極１６６に電圧を印加する。圧電層１６０のうち、上部電極１６４および下部電極１６６に挟まれた部分には電界が生じる。その電界によって、圧電層１６０は変形する。圧電層１６０が変形することによって振動板１７６のうちの振動領域がたわみ振動する。圧電層１６０が変形した後しばらくは、たわみ振動がアクチュエータ１０６の振動部に残留する。

【００４０】残留振動は、アクチュエータ１０６の振動部と媒体との自由振動である。従って、圧電層１６０に印加する電圧をパルス波形あるいは矩形波とすることで、電圧を印加した後に振動部と媒体との共振状態を容易に得ることができる。残留振動は、アクチュエータ１０６の振動部を振動させるため、圧電層１６０をも変形する。従って、圧電層１６０は逆起電力を発生する。その逆起電力は、上部電極１６４、下部電極１６６、上部電極端子１６８および下部電極端子１７０を介して検出される。検出された逆起電力によって、共振周波数が特定できるため、液体容器内の液体の状態を検出することができる。

【００４１】一般に、共振周波数ｆｓは、

$$ｆｓ＝１／（２＊π＊(M＊Cact)^{1/2}) \quad (式1)$$

で表される。ここで、Mは振動部のイナータンスMactと付加イナータンスM’との和である。Cactは振動部のコンプライアンスである。

【００４２】図１（Ｃ）は、本実施例において、キャビティにインクが残存していないときのアクチュエータ１０６の断面図である。図２（Ａ)および図２（Ｂ)は、キャビティにインクが残存していないときのアクチュエータ１０６の振動部およびキャビティ１６２の等価回路で

ある。

【００４３】Mactは、振動部の厚さと振動部の密度と

$$Mact = Mpzt + Melectrode1 + Melectrode2 + Mvib \quad (式２)$$

と表される。ここで、Mpztは、振動部における圧電層１６０の厚さと圧電層１６０の密度との積を圧電層１６０の面積で除したものである。Melectrodelは、振動部における上部電極１６４の厚さと上部電極１６４の密度との積を上部電極１６４の面積で除したものである。Melectrode2は、振動部における下部電極１６６の厚さと下部電極１６６の密度との積を下部電極１６６の面積で除したものである。Mvibは、振動部における振動板１７６の厚さと振動板１７６の密度との積を振動板１７６の振動領域の面積で除したものである。ただし、Mactを振動部全体としての厚さ、密度および面積から算出することができるように、本実施例では、圧電層１６０、上部電極１６４、下部電極１６６および振動板１７６の振動領域のそれぞれの面積は、上述のような大小関係を有するものの、相互の面積の差は微小であることが好ましい。また、本実施例において、圧電層１６０、上部電極１６４および下部電極１６６においては、それらの主要部である円形部分以外の部分は、主要部に対して無視できるほど微小であることが好ましい。従って、アクチュエータ１０６において、Mactは、上部電極１６４、下部電極１６６、圧電層１６０および振動板１７６のうちの振動領域のそれぞれのイナータンスの和である。また、コンプライアンスCactは、上部電極１６４、下部電極１６６、圧電層１６０および振動板１７６のうちの振動領域によって形成される部分のコンプライアンスである。

【００４４】尚、図２（A)、図２（B)、図２（D)、図２（F)は、アクチュエータ１０６の振動部およびキャビティ１６２の等価回路を示すが、これらの等価回路において、Cactはアクチュエータ１０６の振動部のコンプライアンスを示す。Cpzt、Celectrodel、Celectrode2およびCvibはそれぞれ振動部における圧電層１６０、上部電極１６４、下部電極１６６および振動板１７６のコンプライアンスを示す。Cactは、以下の式３で表される。

【００４５】

$$1/Cact = (1/Cpzt) + (1/Celectrode1) + (1/Celectrode2) + (1/Cvib) \quad (式３)$$

式２および式３より、図２（A)は、図２（B)のように表すこともできる。

【００４６】コンプライアンスCactは、振動部の単位面積に圧力をかけたときの変形によって媒体を受容できる体積を表す。また、コンプライアンスCactは、変形のし易さを表すといってもよい。

【００４７】図２（C)は、液体容器に液体が十分に収容され、アクチュエータ１０６の振動領域の周辺に液体が満たされている場合のアクチュエータ１０６の断面図を示す。図２（C)のM’maxは、液体容器に液体が十分に収容され、アクチュエータ１０６の振動領域の周辺に液体が満たされている場合の付加イナータンスの最大値を表す。M’ maxは、

【００４８】

$$M'max = (\pi * \rho / (2*k^3)) * (2*(2*k*a)^3 / (3*\pi)) / (\pi * a^2)^2 \quad (式４)$$

（aは振動部の半径、ρは媒体の密度、kは波数である。）

【００４９】で表される。尚、式４は、アクチュエータ１０６の振動領域が半径aの円形である場合に成立する。付加イナータンスM’は、振動部の付近にある媒体の作用によって、振動部の質量が見かけ上増加していることを示す量である。式４からわかるように、M’maxは振動部の半径aと、媒体の密度ρとによって大きく変化する。

【００５０】波数kは、

$$k = 2 * \pi * fact / c \quad (式５)$$

（factは液体が触れていないときの振動部の共振周波数である。cは媒体中を伝播する音響の速度である。）

【００５１】で表される。

【００５２】図２（D)は、液体容器に液体が十分に収容され、アクチュエータ１０６の振動領域の周辺に液体が満たされている図２（C)の場合のアクチュエータ１０６の振動部およびキャビティ１６２の等価回路を示す。

【００５３】図２（E)は、液体容器の液体が消費され、アクチュエータ１０６の振動領域の周辺に液体が無いものの、アクチュエータ１０６のキャビティ１６２内には液体が残存している場合のアクチュエータ１０６の断面図を示す。式４は、例えば、液体容器に液体が満たされている場合に、インクの密度ρなどから決定される最大のイナータンスM’maxを表す式である。一方、液体容器内の液体が消費され、キャビティ１６２内に液体が残留しつつアクチュエータ１０６の振動領域の周辺にある液体が気体または真空になった場合には、

【００５４】

$$M' = \rho * t / S \quad (式６)$$

と表せる。tは、振動にかかわる媒体の厚さである。Sは、アクチュエータ１０６の振動領域の面積である。この振動領域が半径aの円形の場合は、$S = \pi * a^2$である。従って、付加イナータンスM’は、液体容器に液体が十分に収容され、アクチュエータ１０６の振動領域の周辺に液体が満たされている場合には、式４に従う。一方で、液体が消費され、キャビティ１６２内に液体が残留しつつアクチュエータ１０６の振動領域の周辺にある

液体が気体または真空になった場合には、式６に従う。

【００５５】ここで、図２（Ｅ)のように、液体容器の液体が消費され、アクチュエータ１０６の振動領域の周辺に液体が無いものの、アクチュエータ１０６のキャビティ１６２内には液体が残存している場合の付加イナータンスM’を便宜的にM’cavとし、アクチュエータ１０６の振動領域の周辺に液体が満たされている場合の付加イナータンスM’maxと区別する。

【００５６】図２（Ｆ)は、液体容器の液体が消費され、アクチュエータ１０６の振動領域の周辺に液体が無いものの、アクチュエータ１０６のキャビティ１６２内には液体が残存している図２（Ｅ)の場合のアクチュエータ１０６の振動部およびキャビティ１６２の等価回路を示す。

【００５７】ここで、媒体の状態に関係するパラメータは、式６において、媒体の密度ρおよび媒体の厚さｔである。液体容器内に液体が充分に収容されている場合は、アクチュエータ１０６の振動部に液体が接触し、液体容器内に液体が充分に収容されていない場合は、キャビティ内部に液体が残存するか、もしくはアクチュエータ１０６の振動部に気体または真空が接触する。アクチュエータ１０６の周辺の液体が消費され、図２（Ｃ)のM’maxから図２（Ｅ)のM’cavへ移行する過程における付加イナータンスをM’varとすると、液体容器内の液体の収容状態によって、媒体の密度ρや媒体の厚さｔが変化するため、付加イナータンスM’varが変化し、共振周波数ｆｓも変化することになる。従って、共振周波数ｆｓを特定することによって、液体容器内の液体の有無を検出することができる。式６を用いてM’cavを表すと、式６のｔにキャビティの深さｄを代入し、

【００５８】M’cav＝ρ＊ｄ/Ｓ　　（式７）

となる。

【００５９】また、媒体が互いに種類の異なる液体であっても、組成の違いによって密度ρが異なるため、付加イナータンスM´が変化し、共振周波数ｆｓも変化する。従って、共振周波数ｆｓを特定することで、液体の種類を検出できる。尚、アクチュエータ１０６の振動部にインクまたは空気のいずれか一方のみが接触し、混在していない場合には、式４によって計算しても、M’の相違を検出できる。

【００６０】図３（Ａ）は、インクタンク内のインクの量とインクおよび振動部の共振周波数ｆｓとの関係を示すグラフである。ここでは液体の１例としてインクについて説明する。縦軸は、共振周波数ｆｓを示し、横軸は、インク量を示す。インク組成が一定であるとき、インク残量の低下に伴い、共振周波数ｆｓは、上昇する。

【００６１】インク容器にインクが十分に収容され、アクチュエータ１０６の振動領域の周辺にインクが満たされている場合には、その最大付加イナータンスM’maxは式４に表わされる値となる。一方で、インクが消費され、キャビティ１６２内に液体が残留しつつアクチュエータ１０６の振動領域の周辺にインクが満たされていないときには、付加イナータンスM’varは、媒体の厚さｔに基づいて式６によって算出される。式６中のｔは振動にかかわる媒体の厚さであるから、アクチュエータ１０６のキャビティ１６２のｄ(図１（Ｂ）参照)を小さく、即ち、基板１７８を十分に薄くすることによって、インクが徐々に消費されていく過程を検出することもできる（図２（Ｃ)参照）。ここで、ｔinkは振動にかかわるインクの厚さとし、ｔink－maxはM’maxにおけるｔinkとする。例えば、インクカートリッジの底面にアクチュエータ１０６をインクの液面に対してほぼ水平に配備する。インクが消費され、インクの液面がアクチュエータ１０６からｔの高さ以下に達すると、式６によりM’varが徐々に変化し、式１により共振周波数ｆｓが徐々に変化する。従って、インクの液面がｔの範囲内にある限り、アクチュエータ１０６はインクの消費状態を徐々に検出することができる。

【００６２】また、アクチュエータ１０６の振動領域を大きくまたは長くし、かつ縦に配置することによってインクの消費による液面の位置にしたがって、式６中のＳが変化する。従って、アクチュエータ１０６はインクが徐々に消費されていく過程を検出することもできる。例えば、インクカートリッジの側壁にアクチュエータ１０６をインクの液面に対してほぼ垂直に配備する。インクが消費され、インクの液面がアクチュエータ１０６の振動領域に達すると、水位の低下に伴い付加イナータンスM’が減少するので、式１により共振周波数ｆｓが徐々に増加する。従って、インクの液面が、キャビティ１６２の径２ａ（図２（Ｃ)参照）の範囲内にある限り、アクチュエータ１０６はインクの消費状態を徐々に検出することができる。

【００６３】図３(Ａ)の曲線Ｘは、アクチュエータ１０６のキャビティ１６２を十分に浅くした場合や、アクチュエータ１０６の振動領域を十分に大きくまたは長くした場合のインクタンク内に収容されたインクの量とインクおよび振動部の共振周波数ｆｓとの関係を表わしている。インクタンク内のインクの量が減少するとともに、インクおよび振動部の共振周波数ｆｓが徐々に変化していく様子が理解できる。

【００６４】より詳細には、インクが徐々に消費されていく過程を検出することができる場合とは、アクチュエータ１０６の振動領域の周辺において、互いに密度が異なる液体と気体とがともに存在し、かつ振動にかかわる場合である。インクが徐々に消費されていくに従って、アクチュエータ１０６の振動領域周辺において振動にかかわる媒体は、液体が減少する一方で気体が増加する。例えば、アクチュエータ１０６をインクの液面に対して水平に配備した場合であって、ｔinkがｔink－maxより小さいときには、アクチュエータ１０６の振動にかかわ

る媒体はインクと気体との両方を含む。したがって、アクチュエータ１０６の振動領域の面積Ｓとすると、式４のM’max以下になった状態をインクと気体の付加質量

$$M' = M'air + M'ink = \rho air * t air / S + \rho ink * t ink / S \quad (式8)$$

となる。ここで、M’airは空気のイナータンスであり、M’inkはインクのイナータンスである。ρairは空気の密度であり、ρinkはインクの密度である。ｔairは振動にかかわる空気の厚さであり、ｔinkは振動にかかわるインクの厚さである。アクチュエータ１０６の振動領域周辺における振動にかかわる媒体のうち、液体が減少して気体が増加するに従い、アクチュエータ１０６がインクの液面に対しほぼ水平に配備されている場合には、ｔairが増加し、ｔinkが減少する。それによって、M’varが徐々に減少し、共振周波数が徐々に増加する。よって、インクタンク内に残存しているインクの量またはインクの消費量を検出することができる。尚、式７において液体の密度のみの式となっているのは、液体の密度に対して、空気の密度が無視できるほど小さい場合を想定しているからである。

【００６６】アクチュエータ１０６がインクの液面に対しほぼ垂直に配備されている場合には、アクチュエータ１０６の振動領域のうち、アクチュエータ１０６の振動にかかわる媒体がインクのみの領域と、アクチュエータ１０６の振動にかかわる媒体が気体の領域との並列の等価回路（図示せず）と考えられる。アクチュエータ１０６の振動にかかわる媒体がインクのみの領域の面積をＳinkとし、アクチュエータ１０６の振動にかかわる媒体が気体のみの領域の面積をＳairとすると、

【００６７】

$$1/M' = 1/M'air + 1/M'ink = Sair/(\rho air * t air) + Sink/(\rho ink * t ink) \quad (式9)$$

となる。

【００６８】尚、式９は、アクチュエータ１０６のキャビティにインクが保持されない場合に適用される。アクチュエータ１０６のキャビティにインクが保持される場合については、式７、式８および式９によって計算することができる。

【００６９】一方、基板１７８が厚く、即ち、キャビティ１６２の深さｄが深く、ｄが媒体の厚さｔink-maxに比較的近い場合や、液体容器の高さに比して振動領域が非常に小さいアクチュエータを用いる場合には、実際上はインクが徐々に減少する過程を検出するというよりはインクの液面がアクチュエータの装着位置より上位置か下位置かを検出することになる。換言すると、アクチュエータの振動領域におけるインクの有無を検出することになる。例えば、図３(A)の曲線Ｙは、小さい円形の振動領域の場合におけるインクタンク内のインクの量とインクおよび振動部の共振周波数ｆｓとの関係を示す。インクタンク内のインクの液面がアクチュエータの装着位置を通過する前後におけるインク量Ｑの間で、インクおよび振動部の共振周波数ｆｓが激しく変化している様子が示される。このことから、インクタンク内にインクが所定量残存しているか否かを検出することができる。

【００７０】アクチュエータ１０６を用いて液体の有無を検出する方法は、振動板１７６が、液体と直接接触することで、インクの有無を検出するので、インクの消費量をソフトウェアによって計算する方法に比べ、検出精度が高い。更に、電極を用いて、導電性によりインクの有無を検出する方法は、液体容器への取付位置及びインクの種類によって影響されるが、アクチュエータ１０６を用いて液体の有無を検出する方法は、液体容器への取付位置及びインクの種類によって、影響されない。更に、単一のアクチュエータ１０６を用いて、発振と液体の有無の検出の双方をすることができるので、発振と液体の有無の検出とを異なったセンサを用いて実施する方法と比較して液体容器に取付けるセンサの数を減少することができる。したがって、液体容器を安価に製造できる。更に、圧電層１６０の振動周波数を非可聴領域に設定することで、アクチュエータ１０６の動作中に発生する音を静かにすることができる。

【００７１】図３（Ｂ）は、図３（Ａ）の曲線Ｙにおけるインクの密度とインクおよび振動部の共振周波数ｆｓとの関係を示す。液体の例としてインクを挙げている。図３（Ｂ）に示すように、インク密度が高くなると、付加イナータンスが大きくなるので共振周波数ｆｓが低下する。すなわち、インクの種類によって共振周波数ｆｓが異なる。したがって共振周波数ｆｓを測定することによって、インクを再充填する際に、密度の異なったインクが混入されていないか確認することができる。

【００７２】つまり、互いに種類の異なるインクを収容するインクタンクを識別できる。

【００７３】続いて、液体容器内の液体が空の状態であってもアクチュエータ１０６のキャビティ１６２内に液体が残存するようにキャビティのサイズと形状を設定した時の、液体の状態を正確に検出できる条件を詳述する。アクチュエータ１０６は、キャビティ１６２内に液体が満たされている場合に液体の状態を検出できれば、キャビティ１６２内に液体が満たされていない場合であっても液体の状態を検出できる。

【００７４】共振周波数ｆｓは、イナータンスMの関数である。イナータンスMは、振動部のイナータンスMactと付加イナータンスM’との和である。ここで、付加イナータンスM’が液体の状態と関係する。付加イナー

タンスM’は、振動部の付近にある媒体の作用によって振動部の質量が見かけ上増加していることを示す量である。即ち、振動部の振動によって見かけ上媒体を吸収することによる振動部の質量の増加分をいう。

【００７５】従って、M’cavが式４におけるM’maxよりも大きい場合には、見かけ上吸収する媒体は全てキャビティ１６２内に残存する液体である。よって、液体容器内に液体が満たされている状態と同じである。この場合にはM’が変化しないので、共振周波数ｆｓも変化しない。従って、アクチュエータ１０６は、液体容器内の液体の状態を検出できないことになる。

【００７６】一方、M’cavが式４におけるM’ maxよりも小さい場合には、見かけ上吸収する媒体はキャビティ１６２内に残存する液体および液体容器内の気体または真空である。このときには液体容器内に液体が満たされている状態とは異なりM’が変化するので、共振周波数ｆｓが変化する。従って、アクチュエータ１０６は、液体容器内の液体の状態を検出できる。

【００７７】即ち、液体容器内の液体が空の状態で、アクチュエータ１０６のキャビティ１６２内に液体が残存する場合に、アクチュエータ１０６が液体の状態を正確に検出できる条件は、M’cavがM’maxよりも小さいことである。尚、アクチュエータ１０６が液体の状態を正確に検出できる条件M’max＞M’cavは、キャビティ１６２の形状にかかわらない。

【００７８】ここで、M’cavは、キャビティ１６２の容量とほぼ等しい容量の液体の質量である。従って、M’max＞M’cavの不等式から、アクチュエータ１０６が液体の状態を正確に検出できる条件は、キャビティ１６２の容量の条件として表すことができる。例えば、円形状のキャビティ１６２の開口１６１の半径をaとし、およびキャビティ１６２の深さをｄとすると、

【００７９】$M'max > \rho * d / \pi a^2$　　（式１０）

である。式１０を展開すると

【００８０】ａ／ｄ＞３＊π／８　　（式１１）

という条件が求められる。尚、式１０、式１１は、キャビティ１６２の形状が円形の場合に限り成立する。円形でない場合のM’maxの式を用い、式１０中の$\pi a^2$をその面積と置き換えて計算すれば、キャビティの幅および長さ等のディメンジョンと深さの関係が導き出せる。

【００８１】従って、式１１を満たす開口１６１の半径aおよびキャビティ１６２の深さｄであるキャビティ１６２を有するアクチュエータ１０６であれば、液体容器内の液体が空の状態であって、かつキャビティ１６２内に液体が残存する場合であっても、誤作動することなく液体の状態を検出できる。

【００８２】付加イナータンスM’は音響インピーダンス特性にも影響するので、残留振動によりアクチュエータ１０６に発生する逆起電力を測定する方法は、少なくとも音響インピーダンスの変化を検出しているともいえる。

【００８３】また、本実施例によれば、アクチュエータ１０６が振動を発生してその後の残留振動によりアクチュエータ１０６に発生する逆起電力を測定している。しかし、アクチュエータ１０６の振動部が駆動電圧による自らの振動によって液体に振動を与えることは必ずしも必要ではない。即ち、振動部が自ら発振しなくても、それと接触しているある範囲の液体と共に振動することで、圧電層１６０がたわみ変形する。この残留振動が圧電層１６０に逆起電力電圧を発生させ、上部電極１６４および下部電極１６６にその逆起電力電圧を伝達する。この現象を利用することで媒体の状態を検出してもよい。例えば、インクジェット記録装置において、印字時における印字ヘッドの走査によるキャリッジの往復運動による振動によって発生するアクチュエータの振動部の周囲の振動を利用してインクタンクまたはその内部のインクの状態を検出してもよい。

【００８４】図４（Ａ）および図４（Ｂ）は、アクチュエータ１０６を振動させた後の、アクチュエータ１０６の残留振動の波形と残留振動の測定方法とを示す。インクカートリッジ内のアクチュエータ１０６の装着位置レベルにおけるインク水位の上下は、アクチュエータ１０６が発振した後の残留振動の周波数変化や、振幅の変化によって検出することができる。図４（Ａ）および図４（Ｂ）において、縦軸はアクチュエータ１０６の残留振動によって発生した逆起電力の電圧を示し、横軸は時間を示す。アクチュエータ１０６の残留振動によって、図４（Ａ）および図４（Ｂ）に示すように電圧のアナログ信号の波形が発生する。次に、アナログ信号を、信号の周波数に対応するデジタル数値に変換する。

【００８５】図４（Ａ）および図４（Ｂ）に示した例においては、アナログ信号の４パルス目から８パルス目までの４個のパルスが生じる時間を計測することによって、インクの有無を検出する。

【００８６】より詳細には、アクチュエータ１０６が発振した後、予め設定された所定の基準電圧を低電圧側から高電圧側へ横切る回数をカウントする。デジタル信号を４カウントから８カウントまでの間をＨｉｇｈとし、所定のクロックパルスによって４カウントから８カウントまでの時間を計測する。

【００８７】図４（Ａ）はアクチュエータ１０６の装着位置レベルよりも上位にインク液面があるときの波形である。一方、図４（Ｂ）はアクチュエータ１０６の装着位置レベルにおいてインクが無いときの波形である。図４（Ａ）と図４（Ｂ）とを比較すると、図４（Ａ）の方が図４（Ｂ）よりも４カウントから８カウントまでの時間が長いことがわかる。換言すると、インクの有無によって４カウントから８カウントまでの時間が異なる。この時間の相違を利用して、インクの消費状態を検出することができる。アナログ波形の４カウント目から数える

のは、アクチュエータ１０６の振動が安定してから計測をはじめるためである。４カウント目からとしたのは単なる一例であって、任意のカウントから数えてもよい。ここでは、４カウント目から８カウント目までの信号を検出し、所定のクロックパルスによって４カウント目から８カウント目までの時間を測定する。それによって、共振周波数を求める。クロックパルスは、インクカートリッジに取り付けられる半導体記憶装置等を制御するためのクロックと等しいクロックのパルスであることが好ましい。尚、８カウント目までの時間を測定する必要は無く、任意のカウントまで数えてもよい。図４においては、４カウント目から８カウント目までの時間を測定しているが周波数を検出する回路構成にしたがって、異なったカウント間隔内の時間を検出してもよい。

【００８８】例えば、インクの品質が安定していてピークの振幅の変動が小さい場合には、検出の速度を上げるために４カウント目から６カウント目までの時間を検出することにより共振周波数を求めてもよい。また、インクの品質が不安定でパルスの振幅の変動が大きい場合には、残留振動を正確に検出するために４カウント目から１２カウント目までの時間を検出してもよい。

【００８９】また、他の実施例として所定期間内における逆起電力の電圧波形の波数を数えてもよい（図示せず）。この方法によっても共振周波数を求めることができる。より詳細には、アクチュエータ１０６が発振した後、所定期間だけデジタル信号をＨｉｇｈとし、所定の基準電圧を低電圧側から高電圧側へ横切る回数をカウントする。そのカウント数を計測することによってインクの有無を検出できるのである。

【００９０】さらに、図４(Ａ)および図４(Ｂ)を比較して分かるように、インクがインクカートリッジ内に満たされている場合とインクがインクカートリッジ内に無い場合とでは、逆起電力波形の振幅が異なる。従って、共振周波数を求めることなく、逆起電力波形の振幅を測定することによっても、インクカートリッジ内のインクの消費状態を検出してもよい。より詳細には、例えば、図４(Ａ)の逆起電力波形の頂点と図４(Ｂ) の逆起電力波形の頂点との間に基準電圧を設定する。アクチュエータ１０６が発振した後、所定時間にデジタル信号をＨｉｇｈとし、逆起電力波形が基準電圧を横切った場合には、インクが無いと判断する。逆起電力波形が基準電圧を横切らない場合には、インクが有ると判断する。

【００９１】図５は、アクチュエータ１０６の製造方法を示す。複数のアクチュエータ１０６（図５の例では４個）が一体に形成されている。図５に示した複数のアクチュエータの一体成形物を、それぞれのアクチュエータ１０６において切断することにより、図６に示すアクチュエータ１０６を製造する。図５に示す一体成形された複数のアクチュエータ１０６のそれぞれの圧電素子が円形である場合、一体成形物をそれぞれのアクチュエータ１０６において切断することにより、図１に示すアクチュエータ１０６を製造することができる。複数のアクチュエータ１０６を一体に形成することにより、複数のアクチュエータ１０６を同時に効率良く製造することができ、運搬時の取り扱いが容易となる。

【００９２】アクチュエータ１０６は、薄板又は振動板１７６、基板１７８、弾性波発生手段又は圧電素子１７４、端子形成部材又は上部電極端子１６８、及び端子形成部材又は下部電極端子１７０を有する。圧電素子１７４は、圧電振動板又は圧電層１６０、上電極又は上部電極１６４、及び下電極又は下部電極１６６を含む。基板１７８の上面に振動板１７６が、形成され、振動板１７６の上面に下部電極１６６が形成されている。下部電極１６６の上面には、圧電層１６０が形成され、圧電層１６０の上面に、上部電極１６４が、形成されている。したがって、圧電層１６０の主要部は、上部電極１６４の主要部及び下部電極１６６の主要部によって、上下から挟まれるように形成されている。

【００９３】振動板１７６上に複数（図５の例では４個）の圧電素子１７４が形成されている。振動板１７６の表面に下部電極１６６が形成され、下部電極１６６の表面に圧電層１６０が形成され、圧電層１６０の上面に上部電極１６４が形成される。上部電極１６４及び下部電極１６６の端部に上部電極端子１６８及び下部電極端子１７０が形成される。４個のアクチュエータ１０６は、それぞれ別々に切断されて個別に使用される。

【００９４】図６は、圧電素子が矩形のアクチュエータ１０６の一部分の断面を示す。

【００９５】図７は、図６に示したアクチュエータ１０６の全体の断面を示す。基板１７８の圧電素子１７４と対向する面には、貫通孔１７８ａが形成されている。貫通孔１７８ａは振動板１７６によって封止されている。振動板１７６はアルミナや酸化ジルコニア等の電気絶縁性を備え、かつ弾性変形可能な材料によって形成されている。貫通孔１７８ａと対向するように、圧電素子１７４が振動板１７６上に形成されている。下部電極１６６は貫通孔１７８ａの領域から一方向、図７では左方に延びるように振動板１７６の表面に形成されている。上部電極１６４は貫通孔１７８ａの領域から下部電極とは反対の方向に、図７では右方に延びるように圧電層１６０の表面に形成されている。上部電極端子１６８及び下部電極端子１７０は、それぞれ補助電極１７２及び下部電極１６６の上面に形成されている。下部電極端子１７０は下部電極１６６と電気的に接触し、上部電極端子１６８は補助電極１７２を介して上部電極１６４と電気的に接触して、圧電素子とアクチュエータ１０６の外部との間の信号の受け渡しをする。上部電極端子１６８及び下部電極端子１７０は、電極と圧電層とを合わせた圧電素子の高さ以上の高さを有する。

【００９６】図８は、図５に示したアクチュエータ１０

６の製造方法を示す。まず、グリーンシート９４０にプレスあるいはレーザー加工等を用いて貫通孔９４０ａを穿孔する。グリーンシート９４０は焼成後に基板１７８となる。グリーンシート９４０はセラミック等の材料で形成される。次に、グリーンシート９４０の表面にグリーンシート９４１を積層する。グリーンシート９４１は、焼成後に振動板１７６となる。グリーンシート９４１は、酸化ジルコニア等の材料で形成される。次に、グリーンシート９４１の表面に導電層９４２、圧電層１６０、導電層９４４を圧膜印刷等の方法で順次形成する。導電層９４２は、後に下部電極１６６となり、導電層９４４は、後に上部電極１６４となる。次に、形成されたグリーンシート９４０、グリーンシート９４１、導電層９４２、圧電層１６０、及び導電層９４４を乾燥して焼成する。スペーサ部材９４７、９４８は、上部電極端子１６８と下部電極端子１７０の高さを底上げして圧電素子より高くする。スペーサ部材９４７、９４８は、グリーンシート９４０、９４１と同材料を印刷、あるいはグリーンシートを積層して形成する。このスペーサ部材９４７，９４８により貴金属である上部電極端子１６８及び下部電極端子１７０の材料が少なくて済む上に、上部電極端子１６８及び下部電極端子１７０の厚みを薄くできるので、上部電極端子１６８及び下部電極端子１７０を精度良く印刷でき、さらに安定した高さとすることができる。

【００９７】導電層９４２の形成時に導電層９４４との接続部９４４’及びスペーサ部材９４７及び９４８を同時に形成すると、上部電極端子１６８及び下部電極端子１７０を容易に形成したり、強固に固定することができる。最後に、導電層９４２及び導電層９４４の端部領域に、上部電極端子１６８及び下部電極端子１７０を形成する。上部電極端子１６８及び下部電極端子１７０を形成する際、上部電極端子１６８及び下部電極端子１７０が、圧電層１６０に電気的に接続されるように形成する。

【００９８】図９は、本発明が適用されるインクカートリッジのさらに他の実施形態を示す。図９（Ａ）は、本実施形態によるインクカートリッジの底部の断面図である。本実施形態のインクカートリッジは、インクを収容する容器１の底面１ａに貫通孔１ｃを有する。貫通孔１ｃの底部はアクチュエータ６５０によって塞がれ、インク溜部を形成する。

【００９９】図９（Ｂ）は、図９（Ａ）に示したアクチュエータ６５０及び貫通孔１ｃの詳細な断面を示す。図９（Ｃ）は、図９（Ｂ）に示したアクチュエータ６５０及び貫通孔１ｃの平面を示す。アクチュエータ６５０は振動板７２および振動板７２に固定された圧電素子７３とを有する。振動板７２及び基板７１を介して圧電素子７３が貫通孔１ｃに対向するように、アクチュエータ６５０は、容器１の底面に固定される。振動板７２は、弾性変形可能で耐インク性を備える。

【０１００】容器１のインク量に依存して、圧電素子７３及び振動板７２の残留振動によって発生する逆起電力の振幅及び周波数が変化する。アクチュエータ６５０に対向する位置に貫通孔１ｃが形成されていて、最小限の一定量のインクが貫通孔１ｃに確保される。したがって、貫通孔１ｃに確保されるインク量により決まるアクチュエータ６５０の振動の特性を予め測定しておくことにより、容器１のインクエンドを確実に検出することができる。

【０１０１】図１０は貫通孔１ｃの他の実施形態を示す。図１０（Ａ）、（Ｂ）、及び（Ｃ）のそれぞれにおいて、左側の図は、貫通孔１ｃにインクＫが無い状態を示し、右側の図は、貫通孔１ｃにインクＫが残った状態を示す。図９の実施形態においては、貫通孔１ｃの側面は垂直な壁として形成されている。図１０（Ａ）においては、貫通孔１ｃは、側面１ｄが上下方向に斜めであり外側に拡大して開いている。図１０（Ｂ）においては、段差部１ｅ及び１ｆが、貫通孔１ｃの側面に形成されている。上方にある段差部１ｆが、下方にある段差部１ｅより広くなっている。図１０（Ｃ）においては、貫通孔１ｃは、インクＫを排出しやすい方向、すなわちインク供給口２の方向へ延びる溝１ｇを有する。

【０１０２】図１０(Ａ)～（Ｃ）に示した貫通孔１ｃの形状によれば、インク溜部のインクＫの量を少なくできる。従って、図１および図２で説明したM’ｃａｖをM’ｍａｘと比較して小さくすることができるので、インクエンド時におけるアクチュエータ６５０の振動特性を、容器１に印刷可能な量のインクＫが残存している場合と大きく異ならせることができるので、インクエンドをより確実に検出することができる。

【０１０３】図１１はアクチュエータの他の実施形態を示す斜視図である。アクチュエータ６６０は、アクチュエータ６６０を構成する基板または取付プレート７８の貫通孔１ｃよりも外側にパッキン７６を有する。アクチュエータ６６０の外周にはカシメ孔７７が形成されている。アクチュエータ６６０は、カシメ孔７７を介してカシメにより容器１に固定される。

【０１０４】図１２（Ａ）、（Ｂ）は、アクチュエータの更に他の実施形態を示す斜視図である。本実施形態においては、アクチュエータ６７０は、凹部形成基板８０および圧電素子８２を備える。凹部形成基板８０の一方の面には凹部８１がエッチング等の手法により形成され、他方の面には圧電素子８２が取り付けられる。凹部形成基板８０のうち、凹部８１の底部が振動領域として作用する。従って、アクチュエータ６７０の振動領域は凹部８１の周縁によって規定される。また、アクチュエータ６７０は、図１の実施例によるアクチュエータ１０６のうち、基板１７８および振動板１７６が一体として形成された構造と類似する。従って、インクカートリッ

ジを製造する際に製造工程を短縮することができ、コストを低減させる。アクチュエータ６７０は、容器１に設けられた貫通孔１ｃに埋め込み可能なサイズである。それによって、凹部８１がキャビティとしても作用することができる。尚、図１の実施例によるアクチュエータ１０６を、図１２の実施例によるアクチュエータ６７０と同様に貫通孔１ｃに埋め込み可能なように形成してもよい。

【０１０５】図１３は、アクチュエータ１０６を取り付けモジュール体１００として一体形成した構成を示す斜視図である。モジュール体１００はインクカートリッジの容器１の所定個所に装着される。モジュール体１００は、インク液中の少なくとも音響インピーダンスの変化を検出することにより、容器1内の液体の消費状態を検知するように構成されている。本実施形態のモジュール体１００は、容器１にアクチュエータ１０６を取り付けるための液体容器取付部１０１を有する。液体容器取付部１０１は、平面がほぼ矩形の基台１０２上に駆動信号により発振するアクチュエータ１０６を収容した円柱部１１６を載せた構造になっている。モジュール体１００が、インクカートリッジに装着されたときに、モジュール体１００のアクチュエータ１０６が外部から接触できないように構成されているので、アクチュエータ１０６を外部の接触から保護することができる。なお、円柱部１１６の先端側エッジは丸みが付けられていて、インクカートリッジに形成された孔へ装着する際に嵌めやすくなっている。

【０１０６】図１４は、図１３に示したモジュール体１００の構成を示す分解図である。モジュール体１００は、樹脂からなる液体容器取付部１０１と、プレート１１０および凹部１１３を有する圧電装置装着部１０５とを含む。さらに、モジュール体１００は、リードワイヤ１０４ａ及び１０４ｂ、アクチュエータ１０６、およびフィルム１０８を有する。好ましくは、プレート１１０は、ステンレス又はステンレス合金等の錆びにくい材料から形成される。液体容器取付部１０１に含まれる円柱部１１６および基台１０２は、リードワイヤ１０４ａ及び１０４ｂを収容できるよう中心部に開口部１１４が形成され、アクチュエータ１０６、フィルム１０８、及びプレート１１０を収容できるように凹部１１３が形成される。アクチュエータ１０６はプレート１１０にフィルム１０８を介して接合され、プレート１１０およびアクチュエータ１０６は液体容器取付部１０１に固定される。従って、リードワイヤ１０４ａ及び１０４ｂ、アクチュエータ１０６、フィルム１０８およびプレート１１０は、液体容器取付部１０１に一体として取り付けられる。リードワイヤ１０４ａ及び１０４ｂは、それぞれアクチュエータ１０６の上部電極及び下部電極と結合して圧電層に駆動信号を伝達し、一方、アクチュエータ１０６が検出した共振周波数の信号を記録装置等へ伝達する。アクチュエータ１０６は、リードワイヤ１０４ａ及び１０４ｂから伝達された駆動信号に基づいて一時的に発振する。アクチュエータ１０６は発振後に残留振動し、その振動によって逆起電力を発生させる。このとき、逆起電力波形の振動周期を検出することによって、液体容器内の液体の消費状態に対応した共振周波数を検出することができる。フィルム１０８は、アクチュエータ１０６とプレート１１０とを接着してアクチュエータを液密にする。フィルム１０８は、ポリオレフィン等によって形成し、熱融着で接着することが好ましい。フィルム１０８は、アクチュエータ１０６とプレート１１０とを接着してアクチュエータを液密にする。フィルム１０８は、ポリオレフィンによって形成し、熱融着で接着することが好ましい。アクチュエータ１０６とプレート１１０とをフィルム１０８によって面状に接着して固定することにより、接着の場所によるばらつきが無くなり、振動部以外の部分が振動しない。したがって、アクチュエータ１０６をプレート１１０に接着する前と後における共振周波数の変化が小さい。

【０１０７】プレート１１０は円形状であり、基台１０２の開口部１１４は円筒状に形成されている。アクチュエータ１０６及びフィルム１０８は矩形状に形成されている。リードワイヤ１０４、アクチュエータ１０６、フィルム１０８、及びプレート１１０は、基台１０２に対して着脱可能としてもよい。基台１０２、リードワイヤ１０４、アクチュエータ１０６、フィルム１０８、及びプレート１１０は、モジュール体１００の中心軸に対して対称に配置されている。更に、基台１０２、アクチュエータ１０６、フィルム１０８、及びプレート１１０の中心は、モジュール体１００のほぼ中心軸上に配置されている。

【０１０８】基台１０２の開口部１１４の面積は、アクチュエータ１０６の振動領域の面積よりも大きく形成されている。プレート１１０の中心でアクチュエータ１０６の振動部に直面する位置には、貫通孔１１２が形成されている。図１および図２に示したようにアクチュエータ１０６にはキャビティ１６２が形成され、貫通孔１１２とキャビティ１６２は、共にインク溜部を形成する。プレート１１０の厚さは、残留インクの影響を少なくするために貫通孔１１２の径に比べて小さいことが好ましい。例えば貫通孔１１２の深さはその径の３分の１以下の大きさであることが好ましい。貫通孔１１２は、モジュール体１００の中心軸に対して対称なほぼ真円の形状である。また貫通孔１１２の面積は、アクチュエータ１０６のキャビティ１６２の開口面積よりも大きい。貫通孔１１２の断面の周縁はテーパ形状であっても良いしステップ形状でもよい。モジュール体１００は、貫通孔１１２が容器１の内側へ向くように容器１の側部、上部、又は底部に装着される。インクが消費されアクチュエータ１０６周辺のインクがなくなると、アクチュエータ１

０６の共振周波数が大きく変化するので、インクの水位変化を検出することができる。

【０１０９】図１５は、モジュール体の他の実施形態を示す斜視図である。本実施形態のモジュール体４００は、液体容器取付部４０１に圧電装置装着部４０５が形成されている。液体容器取付部４０１は、平面がほぼ角丸の正方形上の基台４０２上に円柱状の円柱部４０３が形成されている。更に、圧電装置装着部４０５は、円柱部４０３上に立てられた板状要素４０６および凹部４１３を含む。板状要素４０６の側面に設けられた凹部４１３には、アクチュエータ１０６が配置される。なお、板状要素４０６の先端は所定角度に面取りされていて、インクカートリッジに形成された孔へ装着する際に嵌めやすくなっている。

【０１１０】図１６は、図１５に示したモジュール体４００の構成を示す分解斜視図である。図１３に示したモジュール体１００と同様に、モジュール体４００は、液体容器取付部４０１および圧電装置装着部４０５を含む。液体容器取付部４０１は基台４０２および円柱部４０３を有し、圧電装置装着部４０５は板状要素４０６および凹部４１３を有する。アクチュエータ１０６は、プレート４１０に接合されて凹部４１３に固定される。モジュール体４００は、リードワイヤ４０４ａ及び４０４ｂ、アクチュエータ１０６、及びフィルム４０８をさらに有する。

【０１１１】本実施形態によれば、プレート４１０は矩形状であり、板状要素４０６に設けられた開口部４１４は矩形状に形成されている。リードワイヤ４０４ａ及び４０４ｂ、アクチュエータ１０６、フィルム４０８、及びプレート４１０は基台４０２に対して着脱可能として構成しても良い。アクチュエータ１０６、フィルム４０８、及びプレート４１０は、開口部４１４の中心を通り、開口部４１４の平面に対して鉛直方向に延びる中心軸に対して対称に配置されている。更に、アクチュエータ４０６、フィルム４０８、及びプレート４１０の中心は、開口部４１４のほぼ中心軸上に配置されている。

【０１１２】プレート４１０の中心に設けられた貫通孔４１２の面積は、アクチュエータ１０６のキャビティ１６２の開口の面積よりも大きく形成されている。アクチュエータ１０６のキャビティ１６２と貫通孔４１２とは、共にインク溜部を形成する。プレート４１０の厚さは貫通孔４１２の径に比べて小さく、例えば貫通孔４１２の径の３分の１以下の大きさに設定することが好ましい。貫通孔４１２は、モジュール体４００の中心軸に対して対称なほぼ真円の形状である。貫通孔４１２の断面の周縁はテーパ形状であっても良いしステップ形状でもよい。モジュール体４００は、貫通孔４１２が容器１の内部に配置されるように容器１の底部に装着することができる。アクチュエータ１０６が垂直方向に延びるように容器１内に配置されるので、基台４０２の高さを変えてアクチュエータ１０６が容器１内に配置される高さを変えることによりインクエンドの時点の設定を容易に変えることができる。

【０１１３】図１７は、モジュール体の更に他の実施形態を示す。図１３に示したモジュール体１００と同様に、図１７のモジュール体５００は、基台５０２および円柱部５０３を有する液体容器取付部５０１を含む。また、モジュール体５００は、リードワイヤ５０４ａ及び５０４ｂ、アクチュエータ１０６、フィルム５０８、及びプレート５１０をさらに有する。液体容器取付部５０１に含まれる基台５０２は、リードワイヤ５０４ａ及び５０４ｂを収容できるよう中心部に開口部５１４が形成され、アクチュエータ１０６、フィルム５０８、及びプレート５１０を収容できるように凹部５１３が形成される。プアクチュエータ１０６はプレート５１０を介して圧電装置装着部５０５に固定される。従って、リードワイヤ５０４ａ及び５０４ｂ、アクチュエータ１０６、フィルム５０８およびプレート５１０は、液体容器取付部５０１に一体として取り付けられる。本実施形態のモジュール体５００は、平面がほぼ角丸の正方形上の基台上に上面が上下方向に斜めな円柱部５０３が形成されている。円柱部５０３の上面の上下方向に斜めに設けられた凹部５１３上にアクチュエータ１０６が配置されている。

【０１１４】モジュール体５００の先端は傾斜しており、その傾斜面にアクチュエータ１０６が装着されている。そのため、モジュール体５００が容器１の底部又は側部に装着されると、アクチュエータ１０６が容器１の上下方向に対して傾斜する。モジュール体５００の先端の傾斜角度は、検出性能を鑑みてほぼ３０°から６０°の間とすることが望ましい。

【０１１５】モジュール体５００は、アクチュエータ１０６が容器１内に配置されるように容器１の底部又は側部に装着される。モジュール体５００が容器１の側部に装着される場合には、アクチュエータ１０６が、傾斜しつつ、容器１の上側、下側、又は横側を向くように容器１に取り付けられる。一方、モジュール体５００が、容器１の底部に装着される場合には、アクチュエータ１０６が、傾斜しつつ、容器１のインク供給口側を向くように容器１に取り付けられることが好ましい。

【０１１６】図１８は、図１３に示したモジュール体１００を容器１に装着したときのインク容器の底部近傍の断面図である。モジュール体１００は、容器１の側壁を貫通するように装着されている。容器１の側壁とモジュール体１００との接合面には、Ｏリング３６５が設けられ、モジュール体１００と容器１との液密を保っている。Ｏリングでシールが出来るようにモジュール体１００は図１３で説明したような円柱部を備えることが好ましい。モジュール体１００の先端が容器１の内部に挿入されることで、プレート１１０の貫通孔１１２を介して

容器１内のインクがアクチュエータ１０６と接触する。アクチュエータ１０６の振動部の周囲が液体か気体かによってアクチュエータ１０６の残留振動の共振周波数が異なるので、モジュール体１００を用いてインクの消費状態を検出することができる。また、モジュール体１００に限らず、図１５に示したモジュール体４００、図１７に示したモジュール体５００、又は図１９及び図２０に示したモジュール体７００Ａ、７００Ｂ、７５０Ａ、及び７５０Ｂ、及びモールド構造体６００を容器１に装着してインクの有無を検出してもよい。

【０１１７】図１９は、モジュール体１００の更に他の実施形態を示す。図１９（Ａ）のモジュール体７５０Ａはアクチュエータ１０６と基台部３６０とを有する。モジュール体７５０Ａは前面が容器１の側壁の内面と同一面となるように、容器１に装着されている。アクチュエータ１０６は、圧電層１６０、上部電極１６４、下部電極１６６、及び振動板１７６を含む。振動板１７６の上面に下部電極１６６が形成されている。下部電極１６６の上面には圧電層１６０が形成され、圧電層１６０の上面に上部電極１６４が形成されている。したがって、圧電層１６０は、上部電極１６４及び下部電極１６６によって上下から挟まれるように形成されている。圧電層１６０、上部電極１６４、及び下部電極１６６は、圧電素子を形成する。圧電素子は振動板１７６上に形成される。圧電素子及び振動板１７６の振動領域はアクチュエータが実際に振動する振動部である。容器１の側壁には貫通孔３８５が設けられている。したがって、インクは容器１の貫通孔３８５を介して振動板１７６と接触する。

【０１１８】次に図１９（Ａ）に示したモジュール体７５０Ａの動作について説明する。上部電極１６４及び下部電極１６６は圧電層１６０に駆動信号を伝達し、圧電層１６０が検出した共振周波数の信号を記録装置に伝達する。圧電層１６０は上部電極１６４及び下部電極１６６によって伝達された駆動信号により発振して残留振動する。この残留振動により圧電層１６０は逆起電力を発生する。逆起電力波形の振動周期をカウントし、その時点での共振周波数を検出することでインクの有無を検出できる。モジュール体７５０Ａは、アクチュエータ１０６がアクチュエータ１０６の振動部の圧電素子側とは反対の面、すなわち、図１９（Ａ）では、振動板１７６のみが、インク容器１内のインクと接触するように容器１に装着される。図１９（Ａ）のモジュール体７５０Ａは、図１３から図１７に示したリードワイヤ１０４ａ、１０４ｂ、４０４ａ、４０４ｂ、５０４ａ、及び５０４ｂの電極のモジュール体１００への埋め込みが不要となる。そのため成形工程が簡素化される。更に、モジュール体７５０Ａの交換が可能となりリサイクルが可能となる。また更に、アクチュエータ１０６は基台部３６０により保護されているのでアクチュエータ１０６を外部との接触から保護できる。

【０１１９】図１９（Ｂ）はモジュール体７５０Ｂの更に他の実施形態を示す。図１９（Ｂ）のモジュール体７５０Ｂはアクチュエータ１０６と基台部３６０とを有する。モジュール体７５０Ｂは前面が容器１の側壁の内面と同一面となるように、容器１に装着されている。アクチュエータ１０６は、圧電層１６０、上部電極１６４、下部電極１６６、及び振動板１７６を含む。振動板１７６の上面に下部電極１６６が形成されている。下部電極１６６の上面には圧電層１６０が形成され、圧電層１６０の上面に上部電極１６４が形成されている。したがって、圧電層１６０は、上部電極１６４及び下部電極１６６によって上下から挟まれるように形成されている。圧電層１６０、上部電極１６４、及び下部電極１６６は、圧電素子を形成する。圧電素子は振動板１７６上に形成される。圧電素子及び振動板１７６の振動領域はアクチュエータが実際に振動する振動部である。容器１の側壁には薄壁部３８０が設けられている。モジュール体７５０Ｂは、アクチュエータ１０６がアクチュエータ１０６の振動部の圧電素子側とは反対の面、すなわち、図１９（Ｂ）では、振動板１７６のみが、インク容器１の薄壁部３８０と接触するように容器１に装着される。したがって、アクチュエータ１０６の振動部は、薄壁部３８０と共に残留振動する。

【０１２０】次に図１９（Ｂ）に示したモジュール体７５０Ｂの動作について説明する。上部電極１６４及び下部電極１６６は圧電層１６０に駆動信号を伝達し、圧電層１６０が検出した共振周波数の信号を記録装置に伝達する。圧電層１６０は上部電極１６４及び下部電極１６６によって伝達された駆動信号により発振して共振周期で振動する。振動板１７６が、容器１の薄壁部３８０と接触するので、アクチュエータ１０６の振動部は、薄壁部３８０と共に残留振動する。薄壁部３８０の容器１の内面側は、インクと接触するので、アクチュエータ１０６が、薄壁部３８０と共に残留振動する際、この残留振動の共振周波数及び振幅は、インク残量により変化する。この残留振動により圧電層１６０は逆起電力を発生する。逆起電力波形の振動周期をカウントし、その時の共振周波数を検出することによりインク残量を検出することができる。

【０１２１】図１９（Ｂ）のモジュール体７５０Ｂは、図１３から図１７に示したリードワイヤ１０４ａ、１０４ｂ、４０４ａ、４０４ｂ、５０４ａ、及び５０４ｂの電極のモジュール体１００への埋め込みが不要となる。そのため成形工程が簡素化される。更に、モジュール体７５０Ｂの交換が可能となりリサイクルが可能となる。また更に、アクチュエータ１０６は基台部３６０により保護されているのでアクチュエータ１０６を外部との接触から保護できる。

【０１２２】図２０（Ａ）はモジュール体７００Ｂを容

器１に装着したときのインク容器の断面図を示す。本実施例では取付構造体の１つとしてモジュール体７００Ｂを使用する。モジュール体７００Ｂは、液体容器取付部３６０が容器１の内部に突出するようにして容器１に装着されている。取付プレート３５０には貫通孔３７０が形成され、貫通孔３７０とアクチュエータ１０６の振動部が面している。更に、モジュール体７００Ｂの底壁には孔３８２が形成され、圧電装置装着部３６３が形成される。アクチュエータ１０６が孔３８２の一方を塞ぐようにして配備される。したがって、インクは、圧電装置装着部３６３の孔３８２及び取付プレート３５０の貫通孔３７０を介して振動板１７６と接触する。圧電装置装着部３６３の孔３８２及び取付プレート３５０の貫通孔３７０は、共にインク溜部を形成する。圧電装置装着部３６３とアクチュエータ１０６とは、取付プレート３５０及びフィルム部材によって固定されている。液体容器取付部３６０と容器１との接続部にはシーリング構造３７２が設けられている。シーリング構造３７２は合成樹脂等の可塑性の材料により形成されてもよいし、Ｏリングにより形成されてもよい。図２０（Ａ）のモジュール体７００Ｂと容器１とは別体であるが、図２０（Ｂ）ようにモジュール体７００Ｂの圧電装置装着部を容器１の一部で構成してもよい。

【０１２３】図２０（Ａ）のモジュール体７００Ｂは、図１３から図１７に示したリードワイヤのモジュール体への埋め込みが不要となる。そのため成形工程が簡素化される。更に、モジュール体７００Ｂの交換が可能となりリサイクルが可能となる。

【０１２４】インクカートリッジが揺れる際にインクが容器１の上面あるいは側面に付着し、容器１の上面あるいは側面から垂れてきたインクがアクチュエータ１０６に接触することでアクチュエータ１０６が誤作動する可能性がある。しかし、モジュール体７００Ｂは液体容器取付部３６０が容器１の内部に突出しているので、容器１の上面や側面から垂れてきたインクによりアクチュエータ１０６が誤作動しない。

【０１２５】また、図２０（Ａ）の実施例では、振動板１７６と取付プレート３５０の一部のみが、容器１内のインクと接触するように容器１に装着される。図２０（Ａ）の実施例では、図１３から図１７に示したリードワイヤ１０４ａ、１０４ｂ、４０４ａ、４０４ｂ、５０４ａ、及び５０４ｂの電極のモジュール体への埋め込みが不要となる。そのため成形工程が簡素化される。更に、アクチュエータ１０６の交換が可能となりリサイクルが可能となる。

【０１２６】図２０（Ｂ）は、アクチュエータ１０６を容器１に装着したときの実施例としてインク容器の断面図を示す。図２０（Ｂ）の実施例によるインクカートリッジでは、保護部材３６１はアクチュエータ１０６とは別体として容器１に取り付けられている。従って、保護部材３６１とアクチュエータ１０６とはモジュールとして一体となっていないが、一方で、保護部材３６１はアクチュエータ１０６にユーザーの手が触れないように保護することができる。アクチュエータ１０６の前面に設けられる孔３８０は、容器１の側壁に配設されている。アクチュエータ１０６は、圧電層１６０、上部電極１６４、下部電極１６６、振動板１７６及び取付プレート３５０を含む。取付プレート３５０の上面に振動板１７６が形成され、振動板１７６の上面に下部電極１６６が形成されている。下部電極１６６の上面には圧電層１６０が形成され、圧電層１６０の上面に上部電極１６４が形成されている。したがって、圧電層１６０の主要部は、上部電極１６４の主要部及び下部電極１６６の主要部によって上下から挟まれるように形成されている。圧電層１６０、上部電極１６４、及び下部電極１６６のそれぞれの主要部である円形部分は、圧電素子を形成する。圧電素子は振動板１７６上に形成される。圧電素子及び振動板１７６の振動領域はアクチュエータが実際に振動する振動部である。取付プレート３５０には貫通孔３７０が設けられている。更に、容器１の側壁には孔３８０が形成されている。したがって、インクは、容器１の孔３８０及び取付プレート３５０の貫通孔３７０を介して振動板１７６と接触する。容器１の孔３８０及び取付プレート３５０の貫通孔３７０は、共にインク溜部を形成する。また、図２０（Ｂ）の実施例では、アクチュエータ１０６は保護部材３６１により保護されているのでアクチュエータ１０６を外部との接触から保護できる。

【０１２７】尚、図２０（Ａ）および（Ｂ）の実施例における取付プレート３５０に代えて、図１の基板１７８を使用してもよい。

【０１２８】図２０（Ｃ）はアクチュエータ１０６を含むモールド構造体６００を備える実施形態を示す。本実施例では、取付構造体の１つとしてモールド構造体６００を使用する。モールド構造体６００はアクチュエータ１０６とモールド部３６４とを有する。アクチュエータ１０６とモールド部３６４とは一体に成形されている。モールド部３６４はシリコン樹脂等の可塑性の材料によって成形される。モールド部３６４は内部にリードワイヤ３６２を有する。モールド部３６４はアクチュエータ１０６から延びる２本の足を有するように形成されている。モールド部３６４はモールド部３６４と容器１とを液密に固定するために、モールド部３６４の２本の足の端が半球状に形成される。モールド部３６４はアクチュエータ１０６が容器１の内部に突出するよう容器１に装着され、アクチュエータ１０６の振動部は容器１内のインクと接触する。モールド部３６４によって、アクチュエータ１０６の上部電極１６４、圧電層１６０、及び下部電極１６６はインクから保護されている。

【０１２９】図２０（Ｃ）のモールド構造体６００は、モールド部３６４と容器１との間にシーリング構造３７

２が必要ないので、インクが容器１から漏れにくい。また、容器１の外部からモールド構造体６００が突出しない形態であるので、アクチュエータ１０６を外部との接触から保護することができる。インクカートリッジが揺れる際に、インクが容器１の上面あるいは側面に付き、容器１の上面あるいは側面から垂れてきたインクが、アクチュエータ１０６に接触することで、アクチュエータ１０６が、誤作動する可能性がある。モールド構造体６００は、モールド部３６４が、容器１の内部に突出しているので、容器１の上面や側面から垂れてきたインクにより、アクチュエータ１０６が誤作動しない。

【０１３０】図２１は、図１に示したアクチュエータ１０６を用いたインクカートリッジ及びインクジェット記録装置の実施形態を示す。複数のインクカートリッジ１８０は、それぞれのインクカートリッジ１８０に対応した複数のインク導入部１８２及びホルダー１８４を有するインクジェット記録装置に装着される。複数のインクカートリッジ１８０は、それぞれ異なった種類、例えば色のインクを収容する。複数のインクカートリッジ１８０のそれぞれの底面には、少なくとも音響インピーダンスを検出する手段であるアクチュエータ１０６が装着されている。アクチュエータ１０６をインクカートリッジ１８０に装着することによって、インクカートリッジ１８０内のインク残量を検出することができる。

【０１３１】図２２は、インクジェット記録装置のヘッド部周辺の詳細を示す。インクジェット記録装置は、インク導入部１８２、ホルダー１８４、ヘッドプレート１８６、及びノズルプレート１８８を有する。インクを噴射するノズル１９０がノズルプレート１８８に複数形成されている。インク導入部１８２は空気供給口１８１とインク導入口１８３とを有する。空気供給口１８１はインクカートリッジ１８０に空気を供給する。インク導入口１８３はインクカートリッジ１８０からインクを導入する。インクカートリッジ１８０は空気導入口１８５とインク供給口１８７とを有する。空気導入口１８５はインク導入部１８２の空気供給口１８１から空気を導入する。インク供給口１８７はインク導入部１８２のインク導入口１８３にインクを供給する。インクカートリッジ１８０がインク導入部１８２から空気を導入することによって、インクカートリッジ１８０からインク導入部１８２へのインクの供給を促す。ホルダー１８４は、インクカートリッジ１８０からインク導入部１８２を介して供給されたインクをヘッドプレート１８６に連通する。

【０１３２】図２３は、図２０に示したインクカートリッジ１８０の他の実施形態を示す。図２３（Ａ）のインクカートリッジ１８０Ａは、上下方向に斜めに形成された底面１９４ａにアクチュエータ１０６が装着されている。インクカートリッジ１８０のインク容器１９４の内部には、インク容器１９４の内部底面から所定の高さの、アクチュエータ１０６と直面する位置に防波壁１９２が設けられている。アクチュエータ１０６が、インク容器１９４の上下方向に対し斜めに装着されているので、インクの掃けが良好になる。

【０１３３】アクチュエータ１０６と防波壁１９２との間には、インクで満たされた間隙が形成される。また、防波壁１９２とアクチュエータ１０６との間隔は、毛細管力によりインクが保持されない程度に空けられている。インク容器１９４が横揺れしたときに、横揺れによってインク容器１９４内部にインクの波が発生し、その衝撃によって、気体や気泡がアクチュエータ１０６によって検出されてアクチュエータ１０６が誤作動する可能性がある。防波壁１９２を設けることによって、アクチュエータ１０６付近のインクの波を防ぎ、アクチュエータ１０６の誤作動を防ぐことができる。

【０１３４】図２３（Ｂ）のインクカートリッジ１８０Ｂのアクチュエータ１０６は、インク容器１９４の供給口の側壁上に装着されている。インク供給口１８７の近傍であれば、アクチュエータ１０６は、インク容器１９４の側壁又は底面に装着されてもよい。また、アクチュエータ１０６はインク容器１９４の幅方向の中心に装着されることが好ましい。インクは、インク供給口１８７を通過して外部に供給されるので、アクチュエータ１０６をインク供給口１８７の近傍に設けることにより、インクニアエンド時点までインクとアクチュエータ１０６とが確実に接触する。したがって、アクチュエータ１０６はインクニアエンドの時点を確実に検出することができる。

【０１３５】更に、アクチュエータ１０６をインク供給口１８７の近傍に設けることで、インク容器をキャリッジ上のカートリッジホルダに装着する際に、インク容器上のアクチュエータ１０６とキャリッジ上の接点との位置決めが確実となる。その理由は、インク容器とキャリッジとの連結において最も重要なのは、インク供給口と供給針との確実な結合である。少しでもずれがあると供給針の先端を痛めてしまったりあるいはＯリングなどのシーリング構造にダメージを与えてしまいインクが漏れ出してしまうからである。このような問題点を防ぐために、通常インクジェットプリンタはインク容器をキャリッジにマウントする時に正確な位置合わせができるような特別な構造を有している。よって供給口近傍にアクチュエータを配置させることにより、アクチュエータの位置合わせも同時に確実なものとなるのである。さらに、アクチュエータ１０６をインク容器１９４の幅方向の中心に装着することで、より確実に位置合わせすることができる。インク容器が、ホルダへの装着時に幅方向中心線を中心として軸揺動した場合に、もっともその揺れが少ないからである。

【０１３６】図２４はインクカートリッジ１８０の更に他の実施形態を示す。図２４（Ａ）はインクカートリッジ１８０Ｃの断面図、図２４（Ｂ）は図２４（Ａ）に示

したインクカートリッジ１８０Ｃの側壁１９４ｂを拡大した断面図、及び図２４（Ｃ）はその正面からの透視図である。インクカートリッジ１８０Ｃは、半導体記憶手段７とアクチュエータ１０６とが同一の回路基板６１０上に形成されている。図２４（Ｂ）、（Ｃ）に示すように、半導体記憶手段７は回路基板６１０の上方に形成され、アクチュエータ１０６は同一の回路基板６１０において半導体記憶手段７の下方に形成されている。アクチュエータ１０６の周囲を囲むように異型Ｏリング６１４が、側壁１９４ｂに装着される。側壁１９４ｂには、回路基板６１０をインク容器１９４に接合するためのカシメ部６１６が複数形成されている。カシメ部６１６によって回路基板６１０をインク容器１９４に接合し、異型Ｏリング６１４を回路基板６１０に押しつけることで、アクチュエータ１０６の振動領域がインクと接触することをできるようにしつつ、インクカートリッジの外部と内部とを液密に保つ。

【０１３７】半導体記憶手段７及び半導体記憶手段７付近には端子６１２が形成されている。端子６１２は半導体記憶手段７とインクジェット記憶装置等の外部との間の信号の受け渡しをする。半導体記憶手段７は、例えばＥＥＰＲＯＭなどの書き換え可能な半導体メモリによって構成されてもよい。半導体記憶手段７とアクチュエータ１０６とが同一の回路基板６１０上に形成さているので、アクチュエータ１０６及び半導体記憶手段７をインクカートリッジ１８０Ｃに取付ける際に１回の取付け工程で済む。また、インクカートリッジ１８０Ｃの製造時及びリサイクル時の作業工程が簡素化される。更に、部品の点数が削減されるので、インクカートリッジ１８０Ｃの製造コストが低減できる。

【０１３８】アクチュエータ１０６は、インク容器１９４内のインクの消費状態を検知する。半導体記憶手段７はアクチュエータ１０６が検出したインク残量などインクの情報を格納する。すなわち、半導体記憶手段７は検出する際に用いられるインク及びインクカートリッジの特性等の特性パラメータに関する情報を格納する。半導体記憶手段７は、予めインク容器１９４内のインクがフルのとき、すなわちインクがインク容器１９４内に満たされたとき、又はエンドのとき、すなわちインク容器１９４内のインクが消費されたときの共振周波数を特性パラメータの一つとして格納する。インク容器１９４内のインクがフル又はエンド状態の共振周波数は、インク容器が初めてインクジェット記録装置に装着されたときに格納されてもよい。また、インク容器１９４内のインクがフル又はエンド状態の共振周波数は、インク容器１９４の製造中に格納されてもよい。半導体記憶手段７に予めインク容器１９４内のインクがフル又はエンドのときの共振周波数を格納し、インクジェット記録装置側で共振周波数のデータを読出すことによりインク残量を検出する際のばらつきを補正できるので、インク残量が基準値まで減少したことを正確に検出することができる。

【０１３９】図２５は、インクカートリッジ１８０の更に他の実施形態を示す。図２５（Ａ）に示すインクカートリッジ１８０Ｄは、インク容器１９４の側壁１９４ｂに複数のアクチュエータ１０６を装着する。図５に示した、一体成形された複数のアクチュエータ１０６を、これら複数のアクチュエータ１０６として用いることが好ましい。複数のアクチュエータ１０６は、上下方向に間隔をおいて側壁１９４ｂに配置されている。複数のアクチュエータ１０６を上下方向に間隔をおいて側壁１９４ｂに配置することによって、インク残量を段階的に検出することができる。

【０１４０】図２５（Ｂ）に示すインクカートリッジ１８０Ｅは、インク容器１９４の側壁１９４ｂに上下方向に長いアクチュエータ６０６を装着する。上下方向に長いアクチュエータ６０６によって、インク容器１９４内のインク残量の変化を連続的に検出することができる。アクチュエータ６０６の長さは、側壁１９４ｂに高さの半分以上の長さを有することが望ましく、図２５（Ｂ）においては、アクチュエータ６０６は側壁１９４ｂのほぼ上端からほぼ下端までの長さを有する。

【０１４１】図２５（Ｃ）に示すインクカートリッジ１８０Ｆは、図２５（Ａ）に示したインクカートリッジ１８０Ｄと同様に、インク容器１９４の側壁１９４ｂに複数のアクチュエータ１０６を装着し、複数のアクチュエータ１０６の直面に所定の間隔をおいて上下方向に長い防波壁１９２を備える。図５に示した、一体成形された複数のアクチュエータ１０６を、これら複数のアクチュエータ１０６として用いることが好ましい。アクチュエータ１０６と防波壁１９２との間には、インクで満たされた間隙が形成される。また、防波壁１９２とアクチュエータ１０６との間隔は、毛細管力によりインクが保持されない程度に空けられている。インク容器１９４が横揺れしたときに横揺れによってインク容器１９４内部にインクの波が発生し、その衝撃によって気体や気泡がアクチュエータ１０６によって検出されてしまい、アクチュエータ１０６が誤作動する可能性がある。本発明のように防波壁１９２を設けることによって、アクチュエータ１０６付近のインクの波立ちを防ぎ、アクチュエータ１０６の誤作動を防ぐことができる。また、防波壁１９２はインクが揺動することで発生した気泡がアクチュエータ１０６に侵入するのを防ぐ。

【０１４２】図２６は、インクカートリッジ１８０の更に他の実施形態を示す。図２６（Ａ）のインクカートリッジ１８０Ｇは、インク容器１９４の上面１９４ｃから下方に延びる複数の隔壁２１２を有する。それぞれの隔壁２１２の下端とインク容器１９４の底面とは所定の間隔が空けられているので、インク容器１９４の底部は連通している。インクカートリッジ１８０Ｇは複数の隔壁２１２のそれぞれによって区画された複数の収容室２１

３を有する。複数の収容室２１３の底部は互いに連通する。複数の収容室２１３のそれぞれにおいて、インク容器１９４の上面１９４ｃにはアクチュエータ１０６が装着されている。図５に示した、一体成形されたアクチュエータ１０６を、これら複数のアクチュエータ１０６として用いることが好ましい。アクチュエータ１０６は、インク容器１９４の収容室２１３の上面１９４ｃのほぼ中央に配置される。収容室２１３の容量はインク供給口１８７側が最も大きく、インク供給口１８７からインク容器１９４の奥へ遠ざかるにつれて、収容室２１３の容量が徐々に小さくなっている。したがって、アクチュエータ１０６が配置される間隔はインク供給口１８７側が広く、インク供給口１８７からインク容器１９４の奥へと遠ざかるにつれ、狭くなっている。

【０１４３】インクは、インク供給口１８７から排出され、空気が空気導入口１８５から入るので、インク供給口１８７側の収容室２１３からインクカートリッジ１８０Ｇの奥の方の収容室２１３へとインクが消費される。例えば、インク供給口１８７に最も近い収容室２１３のインクが消費されて、インク供給口１８７に最も近い収容室２１３のインクの水位が下がっている間、他の収容室２１３にはインクが満たされている。インク供給口１８７に最も近い収容室２１３のインクが消費され尽くすと、空気が、インク供給口１８７から数えて２番目の収容室２１３に侵入し、２番目の収容室２１３内のインクが消費され始めて、２番目の収容室２１３のインクの水位が下がり始める。この時点で、インク供給室１８７から数えて３番目以降の収容室２１３には、インクが満たされている。このように、インク供給口１８７に近い収容室２１３から遠い収容室２１３へと順番にインクが消費される。

【０１４４】このように、アクチュエータ１０６がそれぞれの収容室２１３ごとにインク容器１９４の上面１９４ｃに間隔をおいて配置されているので、アクチュエータ１０６はインク量の減少を段階的に検出することができる。更に、収容室２１３の容量が、インク供給口１８７から収容室２１３の奥へと徐々に小さくなっているので、アクチュエータ１０６が、インク量の減少を検出する時間間隔が徐々に小さくなり、インクエンドに近づくほど頻度を高く検出することができる。

【０１４５】図２６（Ｂ）のインクカートリッジ１８０Ｈは、インク容器１９４の上面１９４ｃから下方に延びる一つの隔壁２１２を有する。隔壁２１２の下端とインク容器１９４の底面とは所定の間隔が空けられているので、インク容器１９４の底部は連通している。インクカートリッジ１８０Ｈは隔壁２１２によって区画された２室の収容室２１３ａ及び２１３ｂを有する。収容室２１３ａ及び２１３ｂの底部は互いに連通する。インク供給口１８７側の収容室２１３ａの容量はインク供給口１８７から見て奥の方の収容室２１３ｂの容量より大きい。収容室２１３ｂの容量は、収容室２１３ａの容量の半分より小さいことが好ましい。

【０１４６】収容室２１３ｂの上面１９４ｃにアクチュエータ１０６が装着される。更に、収容室２１３ｂには、インクカートリッジ１８０Ｈの製造時に入る気泡を捕らえる溝であるバッファ２１４が形成される。図２６（Ｂ）において、バッファ２１４は、インク容器１９４の側壁１９４ｂから上方に延びる溝として形成される。バッファ２１４はインク収容室２１３ｂ内に侵入した気泡を捕らえるので、気泡によってアクチュエータ１０６がインクエンドと検出する誤作動を防止することができる。また、アクチュエータ１０６を収容室２１３ｂの上面１９４ｃに設けることにより、インクニアエンドが検出されてから完全にインクエンド状態になるまでのインク量に対して、ドットカウンタによって把握した収容室２１３ａでのインクの消費状態に対応した補正をかけることで、最後までインクを消費することができる。更に、収容室２１３ｂの容量を隔壁２１２の長さや間隔を変えたりすることなどによって調節することにより、インクニアエンド検出後の消費可能インク量を変えることができる。

【０１４７】図２６（Ｃ）は、図２６（Ｂ）のインクカートリッジ１８０Ｉの収容室２１３ｂに多孔質部材２１６が充填されている。多孔質部材２１６は、収容室２１３ｂ内の上面から下面までの全空間を埋めるように設置される。多孔質部材２１６は、アクチュエータ１０６と接触する。インク容器が倒れたときや、キャリッジ上での往復運動中に空気がインク収容室２１３ｂ内に侵入してしまい、これがアクチュエータ１０６の誤作動を引き起こす可能性がある。しかし、多孔質部材２１６が備えられていれば、空気を捕らえてアクチュエータ１０６に空気が入るのを防ぐことができる。また、多孔質部材２１６はインクを保持するのでインク容器が揺れることにより、インクがアクチュエータ１０６にかかってアクチュエータ１０６がインク無しをインク有りと誤検出するのを防ぐことができる。多孔質部材２１６は最も容量が小さい収容室２１３に設置することが好ましい。また、アクチュエータ１０６を収容質２１３ｂの上面１９４ｃに設けることにより、インクニアエンドが検出されてから完全にインクエンド状態になるまでのインク量に補正をかけ、最後までインクを消費することができる。更に、収容室２１３ｂの容量を隔壁２１２の長さや間隔を変えたりすることなどによって調節することにより、インクニアエンド検出後の消費可能インク量を変えることができる。

【０１４８】図２６（Ｄ）は、図２６（Ｃ）のインクカートリッジ１８０Ｉの多孔質部材２１６が孔径の異なる２種類の多孔質部材２１６Ａ及び２１６Ｂによって構成されているインクカートリッジ１８０Ｊを示す。多孔質部材２１６Ａは、多孔質部材２１６Ｂの上方に配置され

ている。上側の多孔質部材２１６Ａの孔径は、下側の多孔質部材２１６Ｂの孔径より大きい。もしくは、多孔質部材２１６Ａは、多孔質部材２１６Ｂよりも液体親和性が低い部材で形成される。孔径の小さい多孔質部材２１６Ｂの方が孔径の大きい多孔質部材２１６Ａより毛細管力は大きいので、収容室２１３ｂ内のインクが下側の多孔室部材２１６Ｂに集まり、保持される。したがって、一度空気がアクチュエータ１０６まで到達してインク無しを検出すると、インクが再度アクチュエータに到達してインク有りと検出することが無い。更に、アクチュエータ１０６から遠い側の多孔質部材２１６Ｂにインクが吸収されることで、アクチュエータ１０６近傍のインクの捌けが良くなり、インク有無を検出するときの音響インピーダンス変化の変化量が大きくなる。また、アクチュエータ１０６を収容質２１３ｂの上面１９４ｃに設けることにより、インクニアエンドが検出されてから完全にインクエンド状態になるまでのインク量に補正をかけ、最後までインクを消費することができる。更に、収容室２１３ｂの容量を隔壁２１２の長さや間隔を変えたりすることなどによって調節することにより、インクニアエンド検出後の消費可能インク量を変えることができる。

【０１４９】図２７は、図２６（Ｃ）に示したインクカートリッジ１８０Ｉの他の実施形態であるインクカートリッジ１８０Ｋを示す断面図である。図２７に示すインクカートリッジ１８０の多孔質部材２１６は、多孔質部材２１６の下部の水平方向の断面積が、インク容器１９４の底面の方向にむけて徐々に小さくなるように圧縮され、孔径が小さくなるよう設計されている。図２７（Ａ）のインクカートリッジ１８０Ｋは、多孔質部材２１６の下の方の孔径が小さくなるように圧縮するために側壁にリブが設けられている。多孔質部材２１６下部の孔径は圧縮されることにより、小さくなっているので、インクは多孔質部材２１６下部へと集められ、保持される。アクチュエータ１０６から遠い側の多孔質部材２１６下部にインクが吸収されることで、アクチュエータ１０６近傍のインクの捌けが良くなり、インク有無を検出するときの音響インピーダンス変化の変化量が大きくなる。したがって、インクが揺れることによってインクカートリッジ１８０Ｋ上面に装着されたアクチュエータ１０６にインクがかかっていしまい、アクチュエータ１０６が、インク無しをインク有りと誤検出することを防止することができる。

【０１５０】一方、図２７（Ｂ）及び図２７（Ｃ）のインクカートリッジ１８０Ｌは、多孔質部材２１６の下部の水平方向の断面積が、インク容器１９４の幅方向において、インク容器１９４の底面にむけて徐々に小さくなるよう圧縮するために、収容室の水平方向の断面積がインク容器１９４の底面の方向にむけて徐々に小さくなっている。多孔質部材２１６下部の孔径は圧縮されることにより、小さくなっているので、インクは多孔質部材２１６の下部へと集められ、保持される。アクチュエータ１０６から遠い側の多孔質部材２１６Ｂの下部にインクが吸収されることで、アクチュエータ１０６近傍のインクの捌けが良くなり、インク有無を検出するときの音響インピーダンス変化の変化量が大きくなる。したがって、インクが揺れることによって、インクカートリッジ１８０Ｌの上面に装着されたアクチュエータ１０６にインクがかかっていしまい、アクチュエータ１０６が、インク無しをインク有りと誤検出することを防止することができる。

【０１５１】図２８は、アクチュエータ１０６を用いたインクカートリッジの更に他の実施形態を示す。図２８（Ａ）のインクカートリッジ２２０Ａは、インクカートリッジ２２０Ａの上面から下方へと延びるように設けられた第１の隔壁２２２を有する。第１の隔壁２２２の下端とインクカートリッジ２２０Ａの底面との間には所定の間隔が空けられているので、インクは、インクカートリッジ２２０Ａの底面を通じてインク供給口２３０へ流入できる。第１の隔壁２２２よりインク供給口２３０側には、インクカートリッジ２２０Ａの底面より上方に延びるように第２の隔壁２２４が、形成されている。第２の隔壁２２４の上端とインクカートリッジ２２０Ａ上面との間には所定の間隔が空けられているので、インクは、インクカートリッジ２２０Ａの上面を通じてインク供給口２３０へ流入できる。

【０１５２】第１の隔壁２２２によって、インク供給口２３０から見て、第１の隔壁２２２の奥の方に第１の収容室２２５ａが形成される。一方、第２の隔壁２２４によって、インク供給口２３０から見て第２の隔壁２２４の手前側に第２の収容室２２５ｂが形成される。第１の収容室２２５ａの容量は、第２の収容室２２５ｂの容量より大きい。第１の隔壁２２２及び第２の隔壁２２４の間に、毛管現象を起こせるだけの間隔が空けられることにより、毛管路２２７が形成される。したがって、第１の収容室２２５ａのインクは、毛管路２２７の毛細管力により、毛管路２２７に集められる。そのため、気体や気泡が第２の収容室２２５ｂへ混入するのを防止することができる。また、第２の収容室２２５ｂ内のインクの水位は、安定的に徐々に下降できる。インク供給口２３０から見て、第１の収容室２２５ａは、第２の収容室２２５ｂより奥に形成されているので、第１の収容室２２５ａのインクが消費された後、第２の収容室２２５ｂのインクが消費される。

【０１５３】インクカートリッジ２２０Ａのインク供給口２３０側の側壁、すなわち第２の収容室２２５ｂのインク供給口２３０側の側壁には、アクチュエータ１０６が装着されている。アクチュエータ１０６は、第２の収容室２２５ｂ内のインクの消費状態を検知する。アクチュエータ１０６を、第２の収容室２２５ｂの側壁に装着

することによって、インクエンドにより近い時点でのインク残量を安定的に検出することができる。更に、アクチュエータ１０６を第２の収容室２２５ｂの側壁に装着する高さを変えることにより、どの時点でのインク残量をインクエンドにするかを、自由に設定することができる。毛管路２２７によって第１の収容室２２５ａから第２の収容室２２５ｂへインクが供給されることにより、アクチュエータ１０６は、インクカートリッジ２２０Ａの横揺れによるインクの横揺れの影響を受けないので、アクチュエータ１０６は、インク残量を確実に測定できる。更に、毛管路２２７が、インクを保持するので、インクが第２の収容室２２５ｂから第１の収容室２２５ａへ逆流するのを防ぐ。

【０１５４】インクカートリッジ２２０Ａの上面には、逆止弁２２８が設けられている。逆止弁２２８によって、インクカートリッジ２２０Ａが横揺れしたときに、インクがインクカートリッジ２２０Ａ外部に漏れるのを防ぐことができる。更に、逆止弁２２８をインクカートリッジ２２０Ａの上面に設置することで、インクのインクカートリッジ２２０Ａからの蒸発を防ぐことができる。インクカートリッジ２２０Ａ内のインクが消費されて、インクカートリッジ２２０Ａ内の負圧が逆止弁２２８の圧力を越えると、逆止弁２２８が開いて、インクカートリッジ２２０Ａに空気を吸入し、その後閉じてインクカートリッジ２２０Ａ内の圧力を一定に保持する。

【０１５５】図２８（Ｃ）及び（Ｄ）は、逆止弁２２８の詳細の断面を示す。図２８（Ｃ）の逆止弁２２８は、ゴムにより形成された羽根２３２ａを有する弁２３２を有する。インクカートリッジ２２０の外部との通気孔２３３が、羽根２３２ａに対向してインクカートリッジ２２０に設けられる。羽根２３２ａによって、通気孔２３３が、開閉される。逆止弁２２８は、インクカートリッジ２２０内のインクが減少し、インクカートリッジ２２０内の負圧が逆止弁２２８の圧力を越えると、羽根２３２ａが、インクカートリッジ２２０の内側に開き、外部の空気をインクカートリッジ２２０内に取り入れる。図２８（Ｄ）の逆止弁２２８は、ゴムにより形成された弁２３２とバネ２３５とを有する。逆止弁２２８は、インクカートリッジ２２０内の負圧が逆止弁２２８の圧力を越えると、弁２３２が、バネ２３５を押圧して開き、外部の空気をインクカートリッジ２２０内に吸入し、その後閉じてインクカートリッジ２２０内の負圧を一定に保持する。

【０１５６】図２８（Ｂ）のインクカートリッジ２２０Ｂは、図２８（Ａ）のインクカートリッジ２２０Ａにおいて逆止弁２２８を設ける代わりに第１の収容室２２５ａに多孔質部材２４２を配置している。多孔質部材２４２は、インクカートリッジ２２０Ｂ内のインクを保持すると共に、インクカートリッジ２２０Ｂが横揺れしたときに、インクがインクカートリッジ２２０Ｂの外部へ漏れるのを防ぐ。

【０１５７】以上、キャリッジに装着される、キャリッジと別体のインクカートリッジにおいて、インクカートリッジ又はキャリッジにアクチュエータ１０６を装着する場合について述べたが、キャリッジと一体化され、キャリッジと共に、インクジェット記録装置に装着されるインクタンクにアクチュエータ１０６を装着してもよい。更に、キャリッジと別体の、チューブ等を介して、キャリッジにインクを供給するオフキャリッジ方式のインクタンクにアクチュエータ１０６を装着してもよい。またさらに、記録ヘッドとインク容器とが一体となって交換可能に構成されたインクカートリッジに、本発明のアクチュエータを装着してもよい。

【０１５８】以上、本発明を実施の形態を用いて説明したが、本発明の技術的範囲は上記実施の形態に記載の範囲には限定されない。上記実施の形態に、多様な変更又は改良を加えることができる。その様な変更又は改良を加えた形態も本発明の技術的範囲に含まれ得ることが、特許請求の範囲の記載から明らかである。

【０１５９】

【発明の効果】本発明の圧電装置、モジュール体、及び液体容器は、液体の残量を正確に検出でき、かつ複雑なシール構造が不要である。

【図面の簡単な説明】

【図１】アクチュエータ１０６の詳細を示す図である。

【図２】アクチュエータ１０６の周辺およびその等価回路を示す図である。

【図３】インクの密度とアクチュエータ１０６によって検出されるインクの共振周波数との関係を示す図である。

【図４】アクチュエータ１０６の逆起電力波形を示す図である。

【図５】アクチュエータ１０６の他の実施形態を示す図である。

【図６】図５に示したアクチュエータ１０６の一部分の断面を示す図である。

【図７】図６に示したアクチュエータ１０６の全体の断面を示す図である。

【図８】図５に示したアクチュエータ１０６の製造方法を示す図である。

【図９】本発明のインクカートリッジの更に他の実施形態を示す図である。

【図１０】貫通孔１ｃの他の実施形態を示す図である。

【図１１】アクチュエータ６６０の他の実施形態を示す図である。

【図１２】アクチュエータ６７０の更に他の実施形態を示す図である。

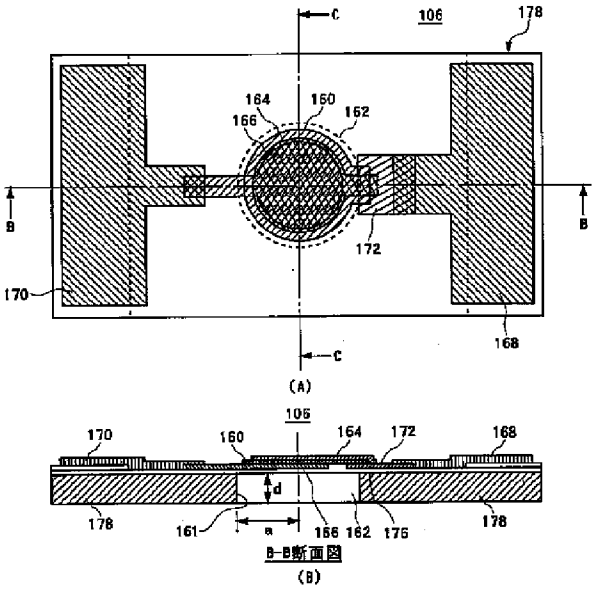
【図１３】モジュール体１００を示す斜視図である。

【図１４】図１３に示したモジュール体１００の構成を示す分解図である。

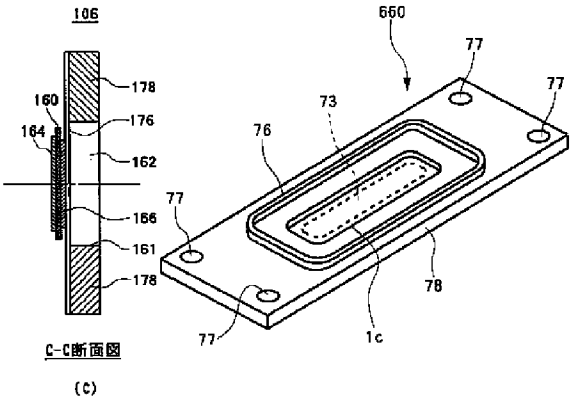
【図１５】モジュール体１００の他の実施形態を示す図である。
【図１６】図１５に示したモジュール体１００の構成を示す分解図である。
【図１７】モジュール体１００の更に他の実施形態を示す図である。
【図１８】図１３に示したモジュール体１００をインク容器１に装着した断面の例を示す図である。
【図１９】モジュール体１００の更に他の実施形態を示す図である。
【図２０】モジュール体１００の更に他の実施形態を示す図である。
【図２１】図１および図２に示したアクチュエータ１０６を用いたインクカートリッジ及びインクジェット記録装置の実施形態を示す図である。
【図２２】インクジェット記録装置の詳細を示す図である。
【図２３】図２２に示したインクカートリッジ１８０の他の実施形態を示す図である。
【図２４】インクカートリッジ１８０の更に他の実施形態を示す図である。
【図２５】インクカートリッジ１８０の更に他の実施形態を示す図である。
【図２６】インクカートリッジ１８０の更に他の実施形態を示す図である。
【図２７】図２６（Ｃ）に示したインクカートリッジ１８０の他の実施形態を示す図である。
【図２８】モジュール体１００を用いたインクカートリッジの更に他の実施形態を示す図である。
【符号の説明】
１・・・容器
１ａ・・・底面
１ｂ・・・側壁
１ｃ、９４０ａ・・・貫通孔
１ｄ、・・・側面
１ｅ、１ｆ・・・段差部
１ｇ、１ｈ・・・溝
２・・・インク供給口
６７・・・板材
６８・・・フロート
７１・・・接着剤層
７８、８０、１７８・・・基板
７３、８２、圧電振動板
７４、７５・・・インク吸収体
７６・・・パッキン
７７・・・カシメ孔
８１・・・凹部
１００、４００，５００、７００・・・モジュール体
１０１、４０１、５０１・・・液体容器取付部
１０２・・・基台
１０４、３６２・・・リードワイヤ
１０５、４０５、５０５・・・圧電装置装着部
１０６、６５０、６６０、６７０・・・アクチュエータ
１０８・・・フィルム
１１０・・・プレート
１１２、４１２、３７０・・・貫通孔
１１３・・・凹部
１１４・・・開口部
１１６・・・円柱部
１６０・・・圧電層
１６２・・・キャビティ
１６４・・・上部電極
１６６・・・下部電極
１６８・・・上部電極端子
１７０・・・下部電極端子
１７２・・・補助電極
１７４・・・圧電素子
１７６・・・振動板
１８０・・・インクカートリッジ
１８１・・・空気供給口
１８２・・・インク導入部
１８３・・・インク導入口
１８４・・・ホルダー
１８５・・・空気導入口
１８６・・・ヘッドプレート
１８７・・・インク供給口
１８８・・・ノズルプレート
１９０・・・ノズル
１９２・・・防波壁
１９４・・・インク容器
１９４ａ・・・底面
１９４ｂ・・・側壁
１９４ｃ・・・上面
２１２・・・隔壁
２１３、２１３ａ、２１３ｂ・・・収容室
２１４・・・バッファ
２１６、２１６ａ、２１６ｂ・・・多孔質部材
２２０・・・インクカートリッジ
２２２・・・第１の隔壁
２２４・・・第２の隔壁
２２５ａ・・・第１の収容室
２２５ｂ・・・第２の収容室
２２７・・・毛管路
２２８・・・逆止弁
２３０・・・インク供給口
２３２・・・弁
２３２ａ・・・羽根
２３３・・・通気孔
２３５・・・バネ
２４２・・・多孔質部材

２５０・・・キャリッジ
２５２・・・記録ヘッド
２５４・・・インク供給針
２５６・・・サブタンクユニット
２５８、２５８’・・・凸部
２６０、２６０’・・・弾性波発生手段
２６２・・・インク室
２６６・・・膜弁
２７０・・・弁体
２７２・・・インクカートリッジ
２７４・・・容器
２７４ａ・・・底面
２７４ｂ・・・側面
２７６・・・インク供給口
２７８・・・凹部
２８０、２８０’・・・ゲル化材
２８２・・・パッキン
２８４・・・バネ
２８６・・・弁体
２８８・・・半導体記憶手段
２９０・・・容器
２９０ａ・・・底面
２９２、２９４、２９６・・・インク室
２９８、３００、３０２・・・インク供給口
３０４、３０６、３０８・・・ゲル化材
３１０、３１２、３１４・・・凹部
３１６・・・板材
３１８・・・フロート
３５０・・・取付プレート
３６０・・・液体容器取付部
３６４・・・モールド部
３７２・・・シーリング構造
４０２、５０２・・・基台
４０３、５０３・・・円柱部
４０４、５０４・・・リードワイヤ
４０８、５０８・・・フィルム
４１０、５１０・・・プレート
４１３、５１３・・・凹部
４１４、５１４・・・開口部
６００・・・モールド構造体
６０６・・・アクチュエータ
６１０・・・回路基板
６１２・・・端子
９４０、９４１・・・グリーンシート
９４２、９４４・・・導電層
９４４’・・・接続部
９４７、９４８・・・スペーサ部材
Δｈ１、Δｈ２・・・液面の変化
Ｋ・・・インク

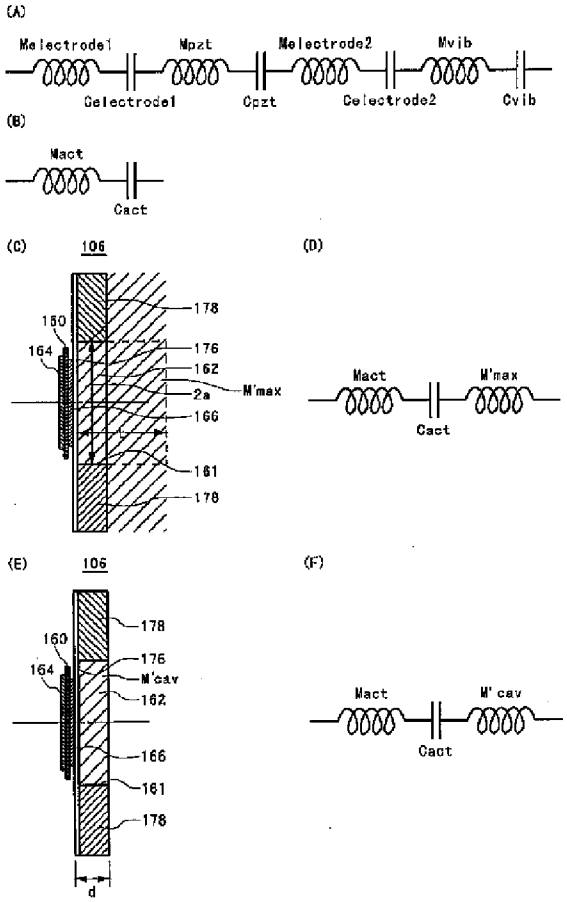
【図１】



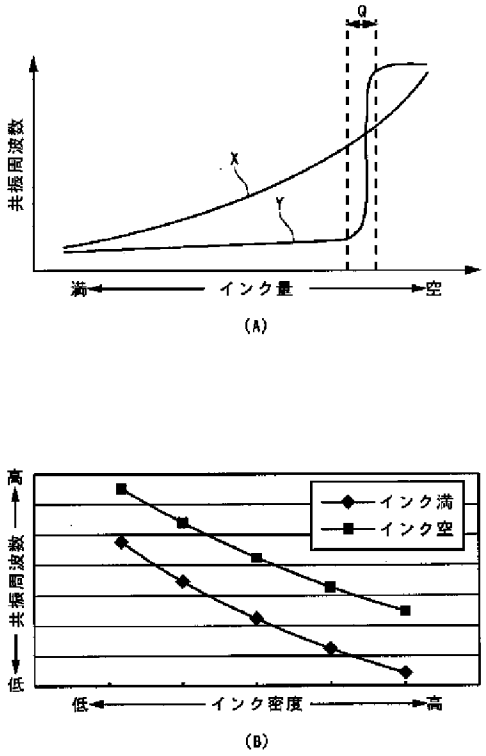

【図１１】



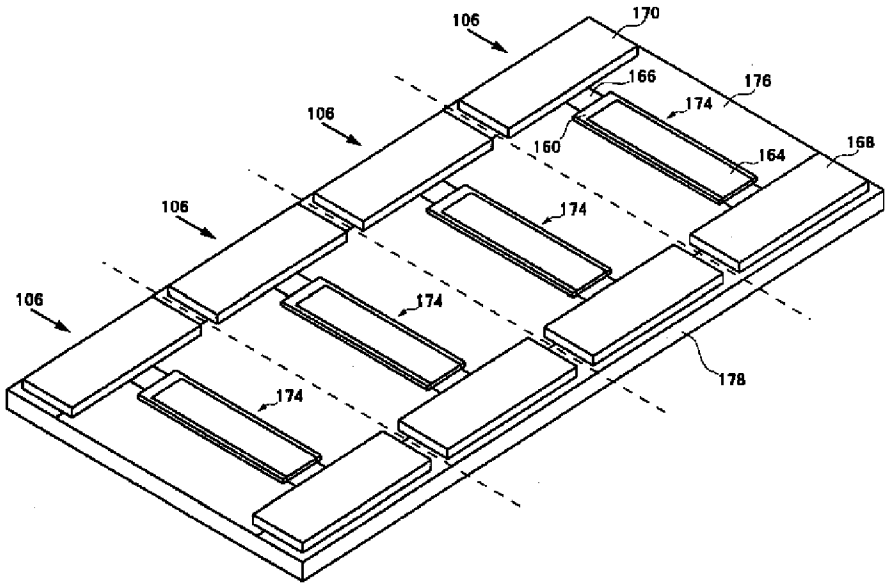
【図２】


(A)
Melectrode1
Mpzt
Melectrode2
Mvib
Celectrode1
Cpzt
Celectrode2
Cvib
(B)
Mact
Cact
(C)
106
178
150
176
164
162
M'max
2a
166
161
178
(D)
Mact
M'max
Cact
(E)
106
178
160
176
164
M'cav
162
166
161
178
d
(F)
Mact
M'cav
Cact

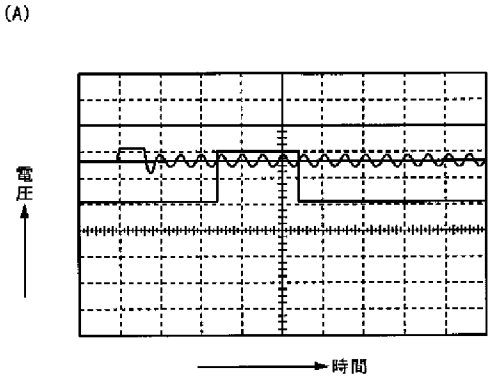
【図３】


Q
共振周波数
X
Y
満
インク量
空
(A)
高
共振周波数
低
インク満
インク空
低
インク密度
高
(B)

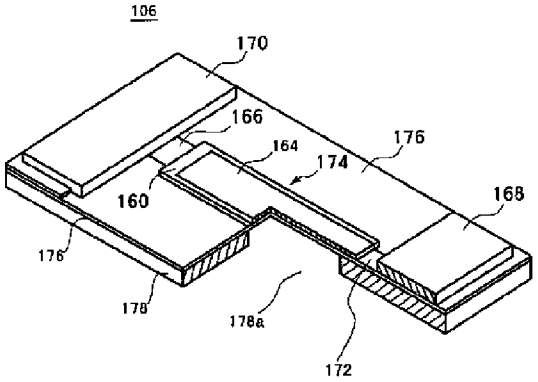
【図５】


106
170
166
176
174
106
160
164
168
106
174
106
174
178
174

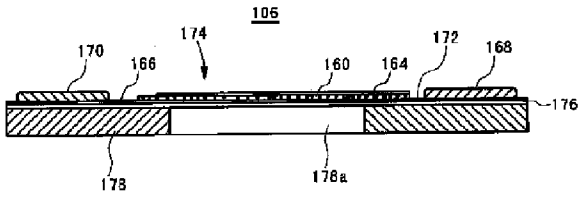
【図４】


(A)
電圧
時間
(B)
電圧
時間

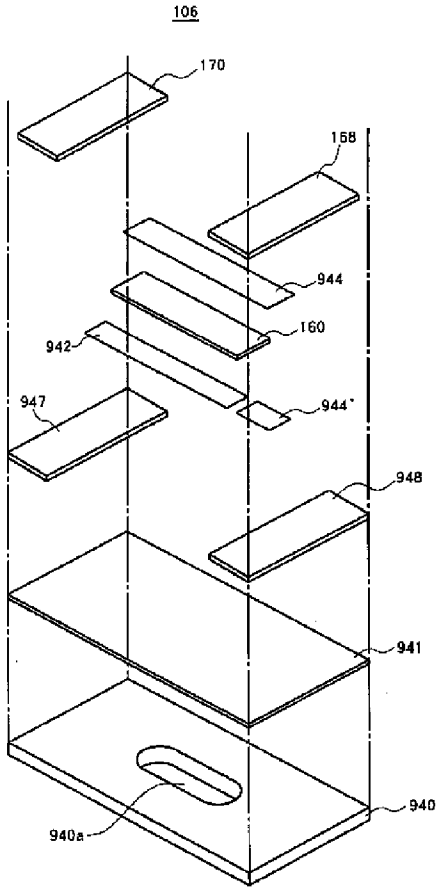
【図６】


106
170
166
164
174
176
160
168
176
178
178a
172

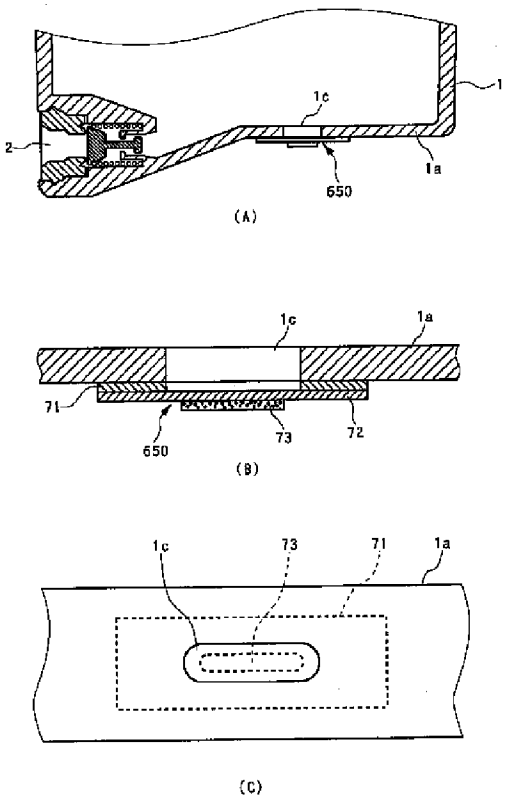
【図７】


106
170
166
174
160
164
172
168
176
178
178a

【図８】


106
170
168
944
160
942
947
944'
948
941
940
940a

【図９】

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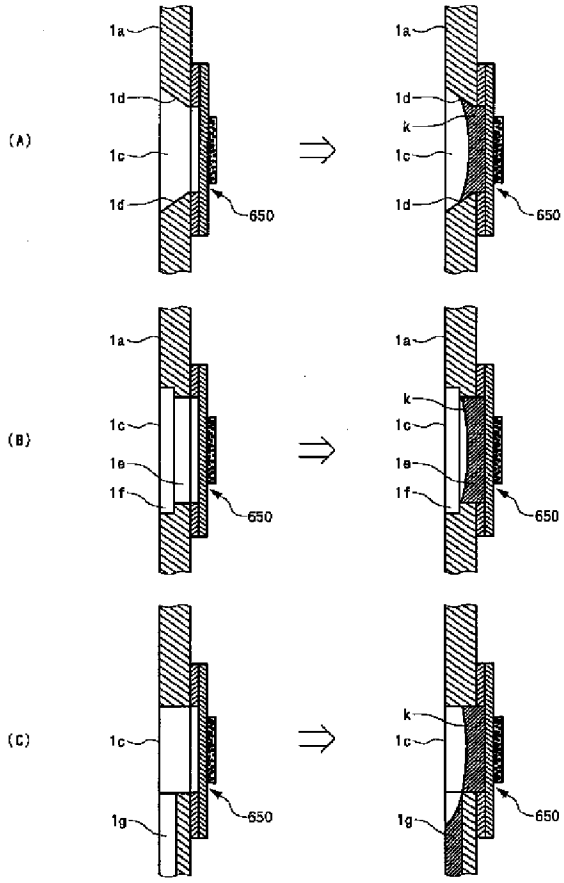


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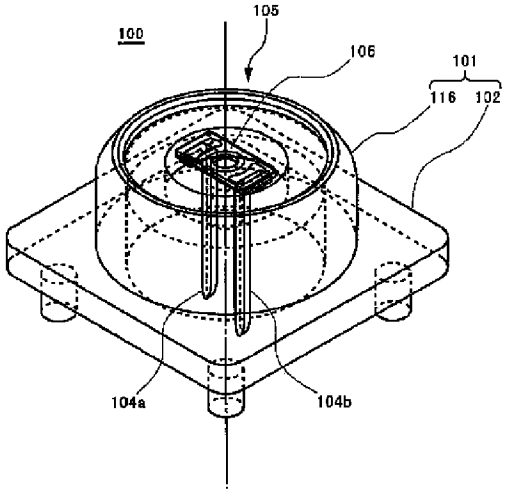


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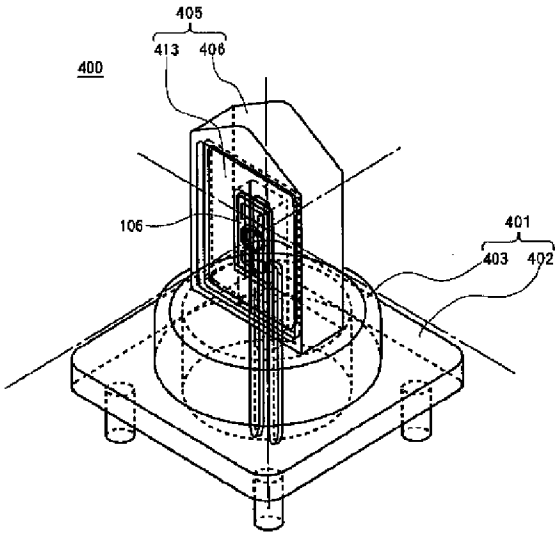

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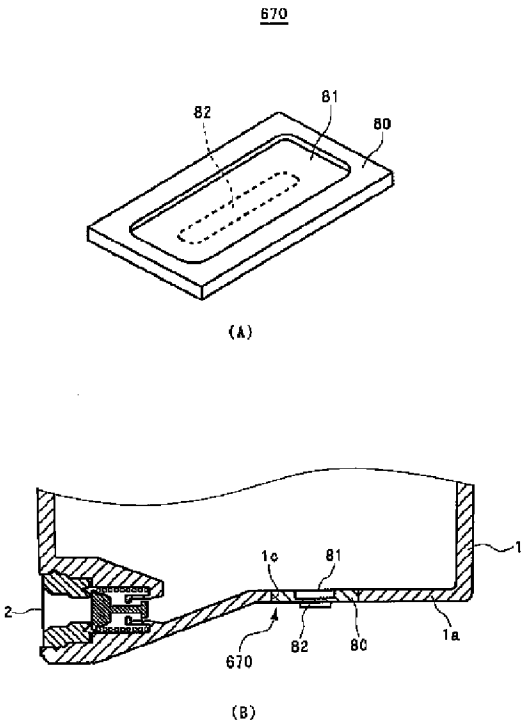
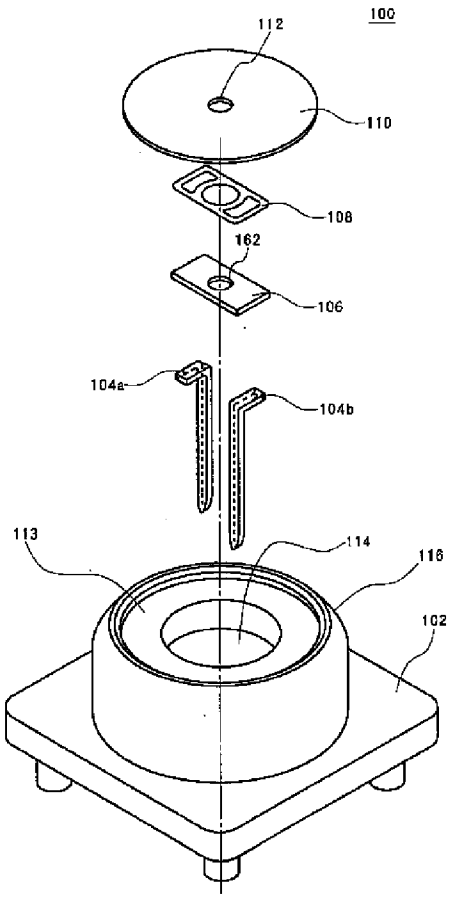
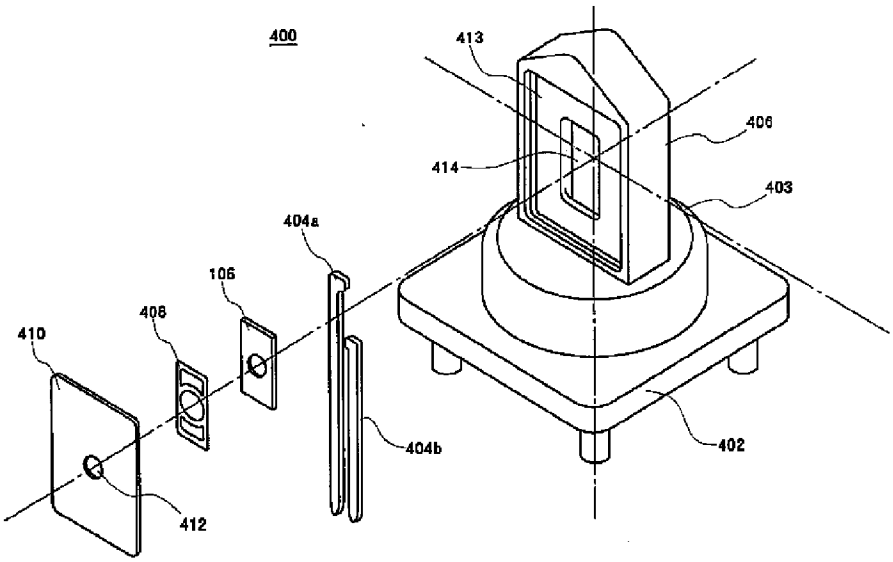

670
82
81
80
(A)
1c
81
1
2
670
82
80
1a
(B)

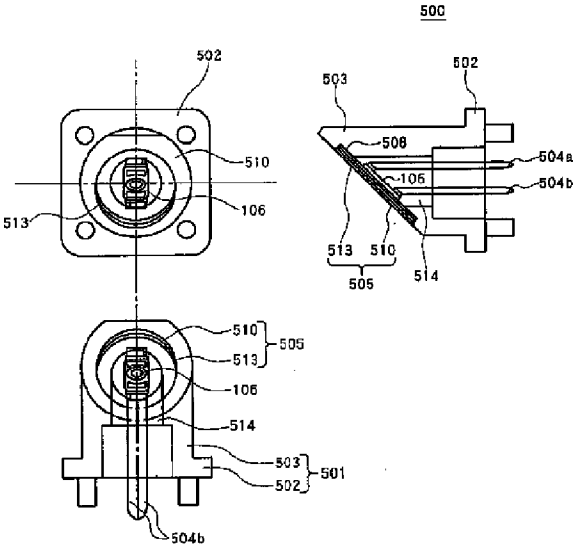
【図１４】


100
112
110
108
162
106
104a
104b
113
114
116
102

【図１６】


400
413
406
414
403
404a
106
408
410
404b
402
412

【図１７】

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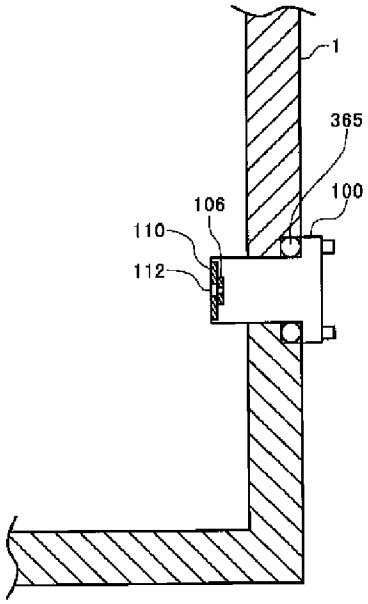


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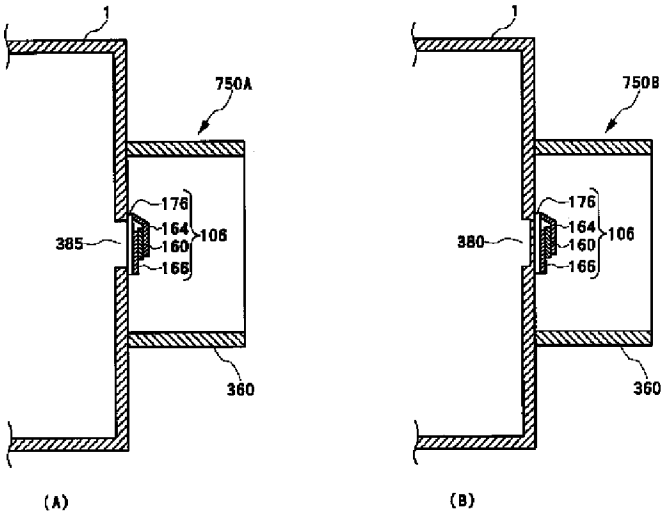


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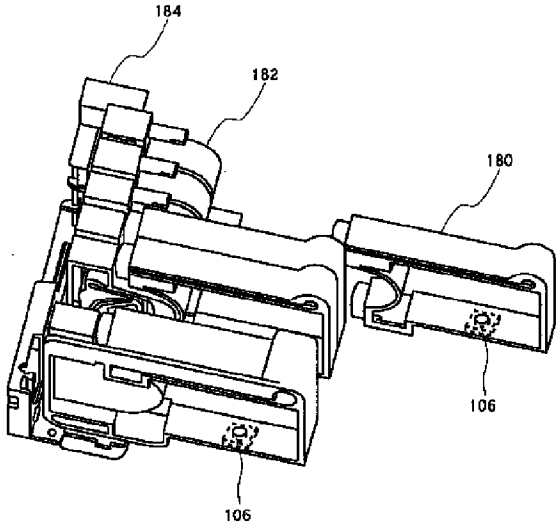

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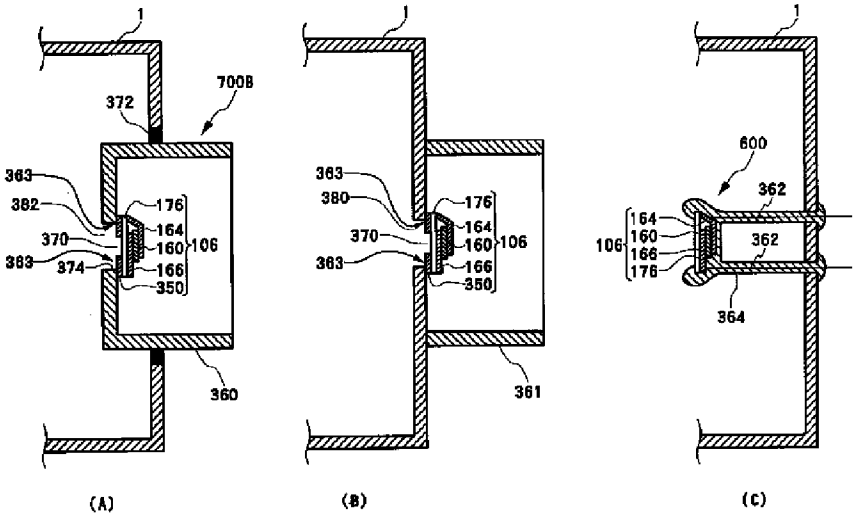
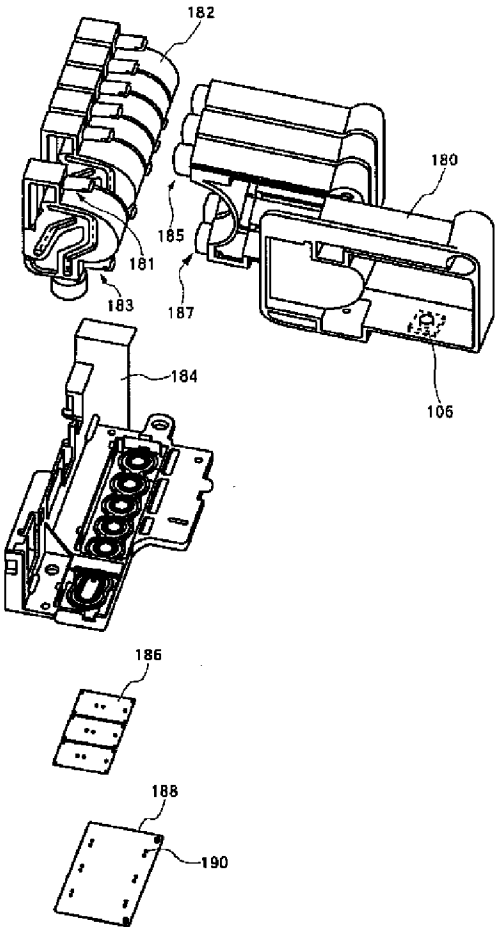
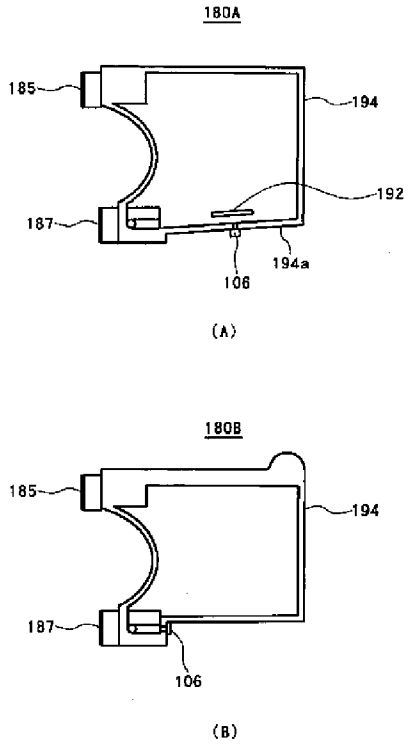

1
700B
372
363
382
370
383
374
176
164
160
166
350
106
360
(A)
1
363
380
370
363
176
164
160
166
350
106
361
(B)
1
600
362
164
160
166
176
106
362
364
(C)

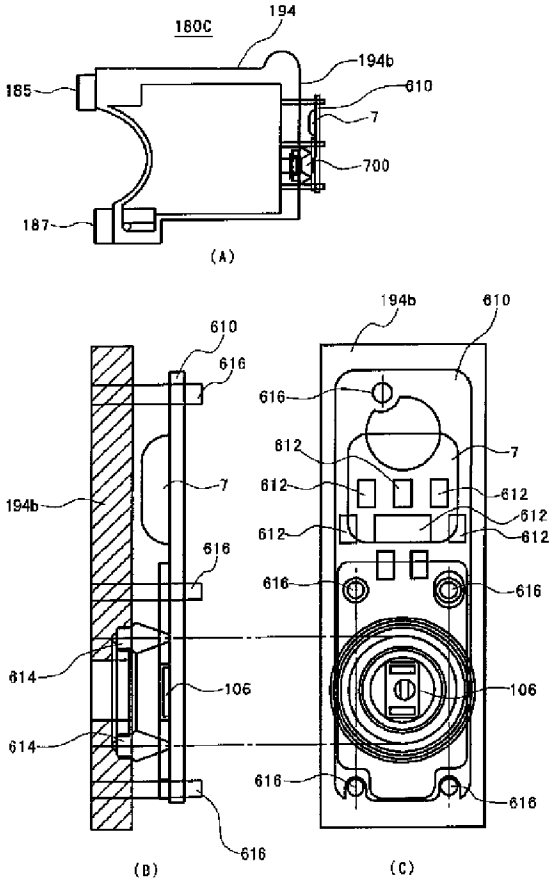
【図２２】


182
180
185
181
183
187
184
106
186
188
190

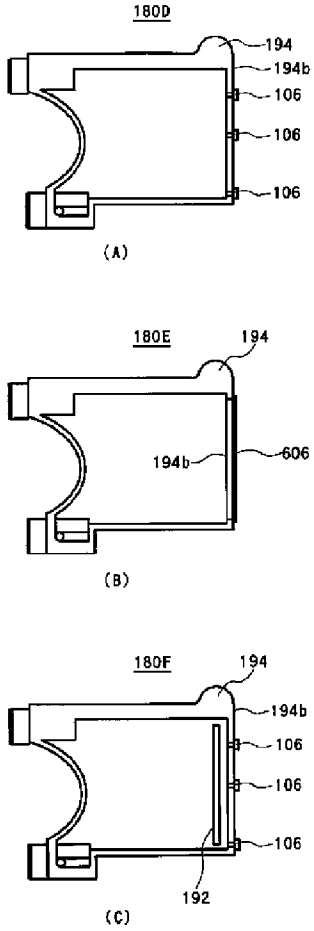
【図２３】


180A
185
194
192
187
194a
106
(A)
180B
185
194
187
106
(B)

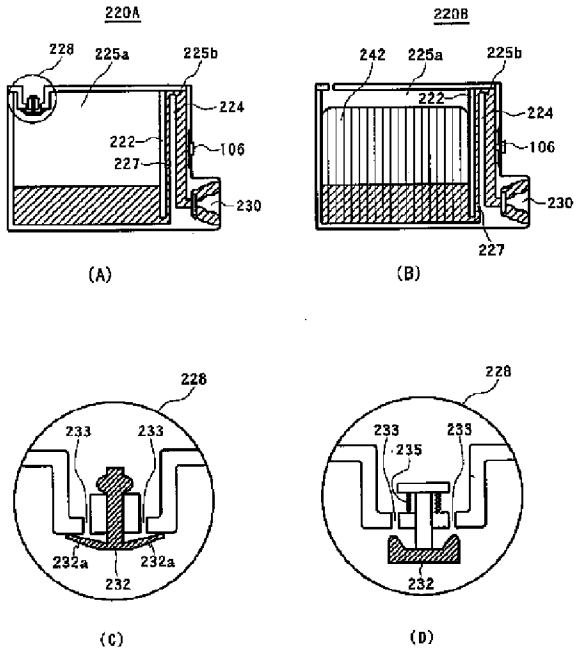
【図２４】


180C
194
194b
610
185
7
700
187
(A)
610
616
194b
7
612
614
106
(B)
(C)

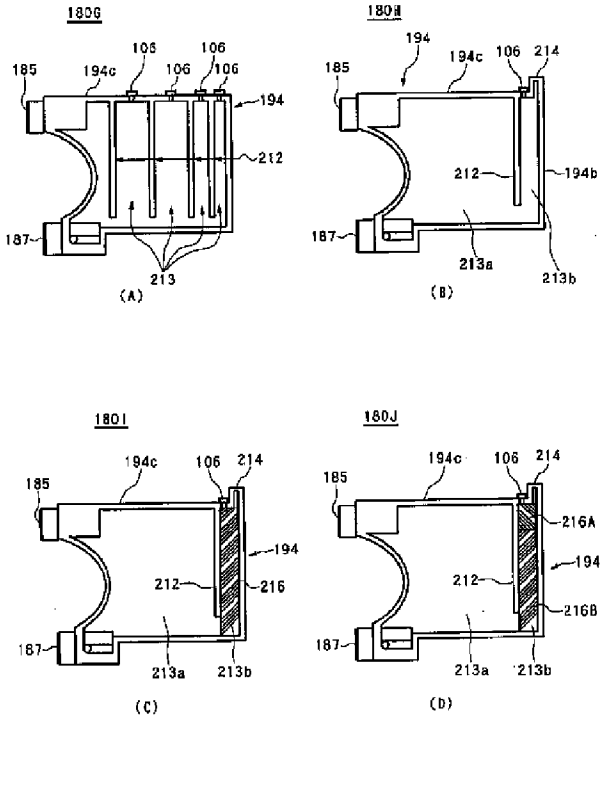
【図２５】


180D
194
194b
106
180E
606
180F
192
(A)
(B)
(C)

【図２８】


220A
220B
228
225a
225b
224
222
227
230
242
233
232a
232
235
(A)
(B)
(C)
(D)

【図２６】

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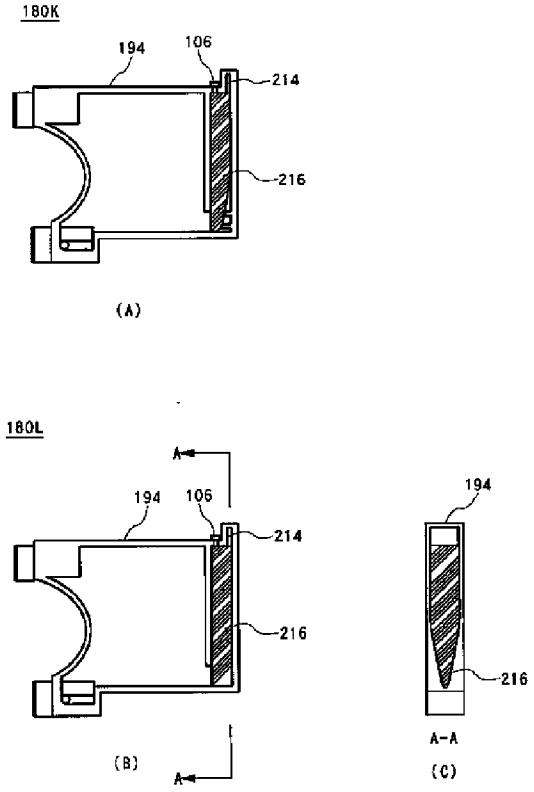


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フロントページの続き

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